SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Sedimentation Basin Design—Camp

Detergent Structure and Action—Gowdy

Sludge Heating at Cleveland—Palocsay

Metal Finishing Wastes—Sundwick and Delos

Radioactive Wastes—Ruchhoft and Setter

JANUARY, 1953—VOL. 25, No. 1

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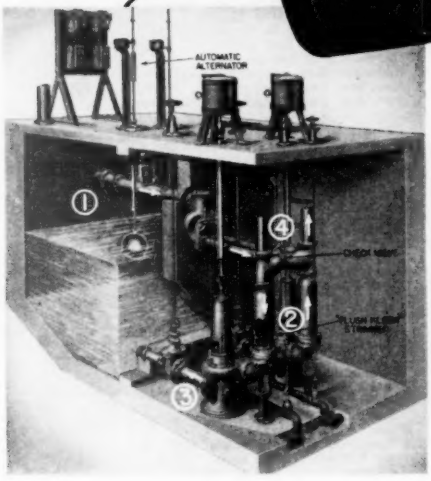
Over 12,000 In Service



Flush-Kleens are absolutely clog proof. Here are the reasons why: Flush-Kleen pumps automatically backwash the strainers, keeping solids from basin and pumps, with the impellers handling water only —this is accomplished as follows:

FILLING WET WELL . . . 1. Sewage flows through inlet pipe. 2. Coarse matter is retained on strainer. 3. Strained sewage flows through idle pump to wet well.

PUMPING . . . 3. Strained sewage is pumped from wet well. 2. Coarse matter is backwashed from strainer. 4. Special check valve closes; sewage and coarse matter are pumped to sewers.

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SCRU-PELLER *Sludge Pumps*

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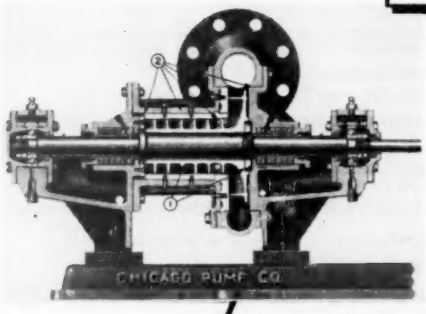

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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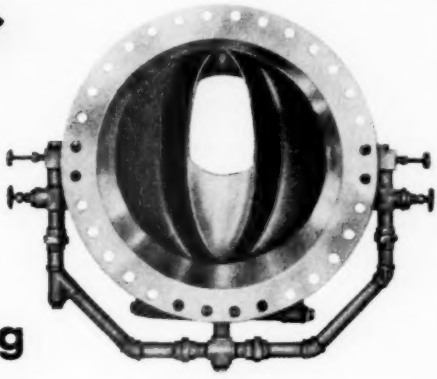

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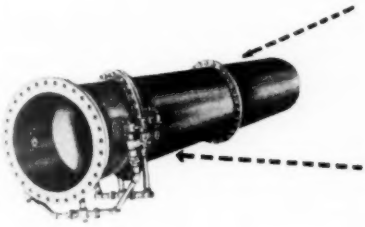

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New York Sewage and Industrial Wastes Assn.	Hotel New Yorker, New York City	Jan. 22–23, 1953
Texas Water and Sewage Works Assn.	Texas A & M College, College Station, Tex.	Mar. 8–12, 1953
New Jersey Sewage and Industrial Wastes Assn.	Hotel Traymore, Atlantic City, N. J.	March 11–13, 1953
Arkansas Water and Sewage Conference	Hotel Marion, Little Rock, Ark.	Mar. 16–18, 1953
South Carolina Water and Sewage Works Assn.	Clemson College, Spartansburg, S. C.	Apr. 2–4, 1953
Kansas Sewage and Industrial Wastes Association	Hotel Broadview, Wichita, Kans.	Apr. 22–24, 1953
California Sewage and Industrial Wastes Association	Mar Monte Hotel, Santa Barbara, Calif.	Apr. 22–25, 1953
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	Apr. 23–25, 1953
Virginia Industrial Wastes and Sewage Works Association	Hotel Jefferson Richmond, Va.	May 21–22, 1953
Central States Sewage and Industrial Wastes Assn.	Hotel Pere Marquette, Peoria, Ill.	June 3–5, 1953
Ohio Sewage and Industrial Wastes Treatment Conference	Mayflower Hotel, Akron, Ohio	June 17–19, 1953
Pennsylvania Sewage and Industrial Wastes Assn.	Pa. State College, State College, Pa.	Aug. 26–28, 1953
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Owensboro Hotel, Owensboro, Ky.	Sept. 21–23, 1953

TWENTY-SIXTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations

in conjunction with

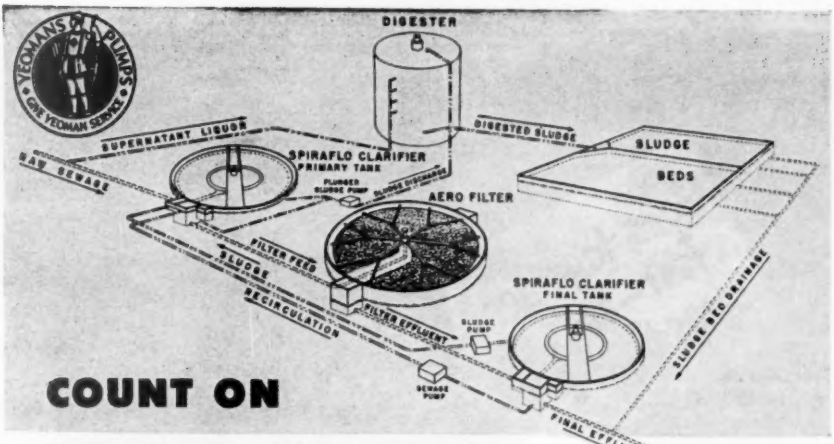
Florida Sewage and Industrial Wastes Association

Municipal (Bayfront Park) Auditorium, Miami, Florida

October 13–16, 1953

Address hotel reservation requests to: FSIWA Convention Housing Bureau, 320 N.E. Fifth Street, Miami, Florida

Nebraska Sewage and Industrial Wastes Association	Hotel Capitol, Lincoln, Nebr.	Nov. 12–13, 1953
Florida Sewage and Industrial Wastes Association	San Carlos Hotel, Pensacola, Fla.	Nov. 16–19, 1953



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• 7-day average overall plant reduction—Suspended Solids 91.5%, B.O.D. 92%—a typical operational report

	Sewage Flow M.G.D.	Raw Sewage		Primary Effluent				Final Effluent				Overall Plant Reduction	
		Sus. Solids PPM	B.O.D. PPM	Sus. Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Sus. Solids Per Cent	B.O.D. Per Cent
6-15	0.2996	210	255	79	62.4	136	46.6	28	64.6	18	86.8	86.6	93.0
6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	308	222	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2666	232	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
Average	0.2456	297	247	85	70.5	132	45.5	24	71.0	20	85.0	91.5	92.0

* Name of plant on request.

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"Aero-Filter" Advantages

- Straight-wall design minimizes construction costs.
- Thorough uniform distribution—therefore costly recirculation for dilution is unnecessary.
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NO NEED TO LET ordinary time-consuming methods of making joints slow down your sewer line jobs—not when you install Transite Sewer Pipe with its new Ring-Tite Coupling.

Just a simple assembly operation with a mechanical coupling puller and this new "packaged" joint is ready for business! No jointing compounds to bother with . . . no heating equipment . . . no special skill is required. And you can check each joint for proper assembly as soon as it is made—*before backfilling.*

Moreover, this easily assembled Ring-Tite Coupling makes a tight joint that *stays* tight in service. This, plus the fact that Transite's long 13-foot lengths mean *fewer* joints in the line, cuts infiltration to a minimum.

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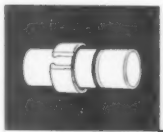
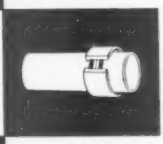
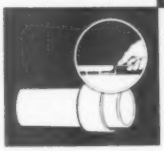


◀ Start of assembly. Two rubber rings and Transite sleeve (cut away to show position of rings) are placed on one of the two pipe ends.

Final position. ▶ Sleeve centered over pipe ends, with the rubber rings tightly compressed between sleeve and pipe.





◀ Checking joint for proper assembly. This is done with a simple gauge immediately after the joint is made . . . *before backfilling.*

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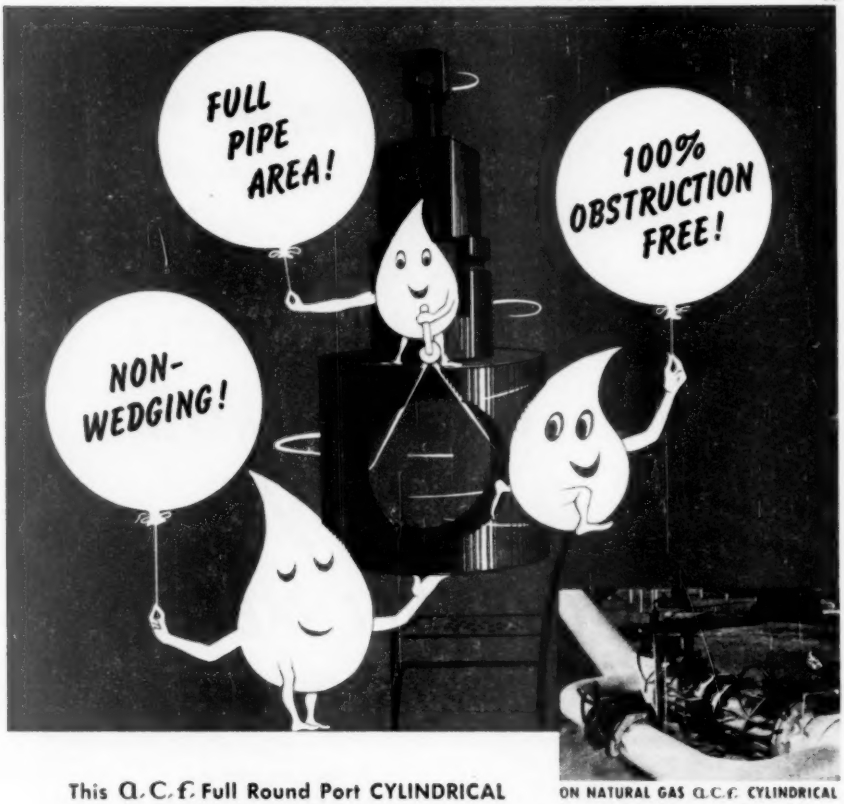

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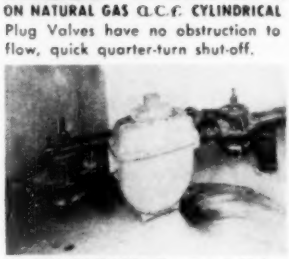

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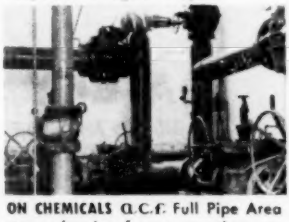
IN SEWAGE PLANTS the a.c.f. Valve provides knife-edge, shearing action, keeps raw sewage lines open.



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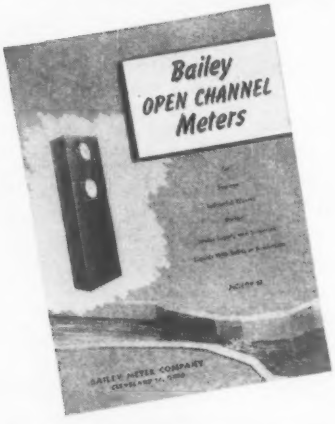

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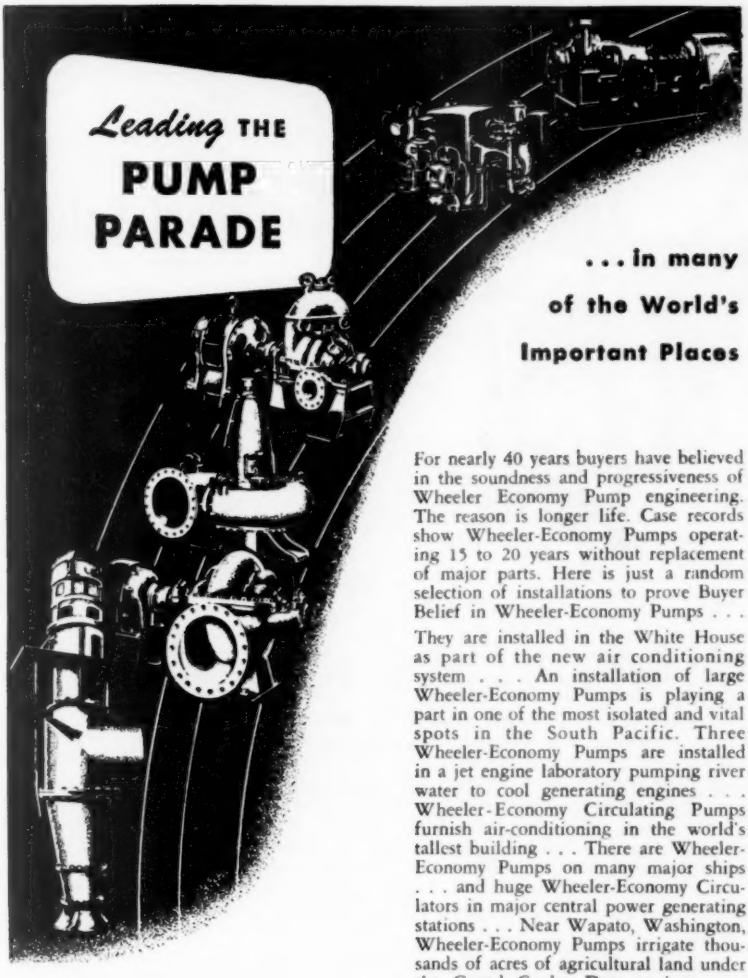

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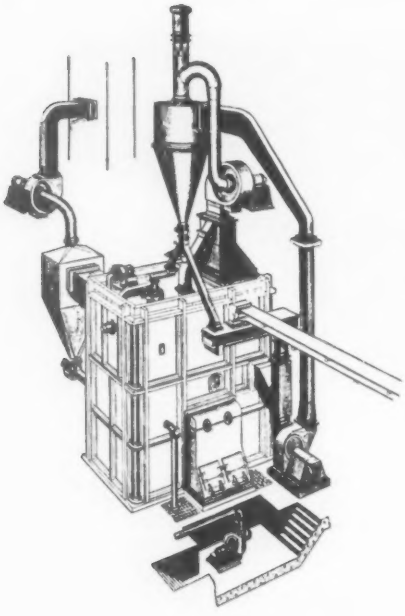

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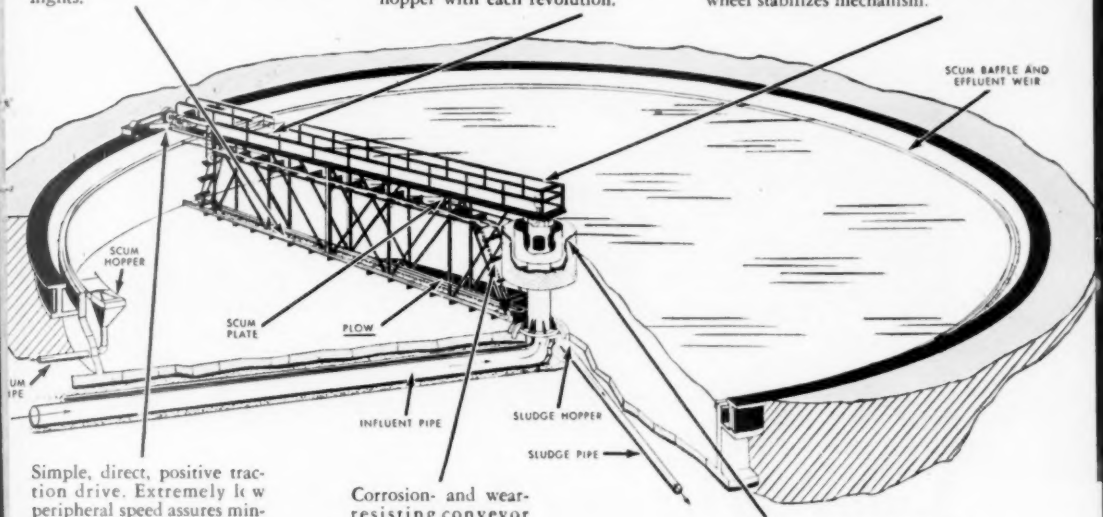

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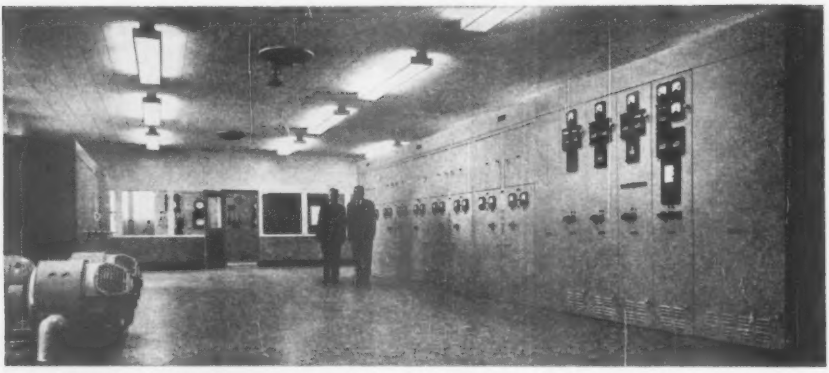

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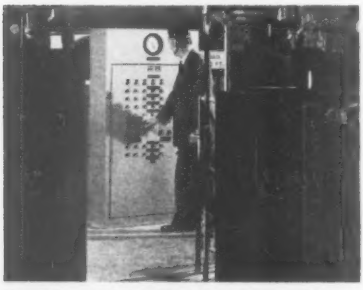

Special control like this chlorinator panel is part of complete G-E equipment for sewage plants.

Available now to all communities faced with the need for new or expanded sewage-treatment facilities is this three-way help from General Electric:

1. **Community-action program,** including the film *Clean Waters* to aid you in increasing public support for necessary new projects.
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3. **Co-ordinated electrical equipment** supplied from the complete G-E line of motors, control and power distribution equipment.

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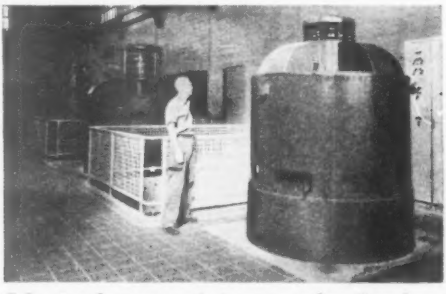
Clean Waters program consists of film, manual *Modern Sewage Treatment,* handout leaflets.



G-E motors for sewage-plant use range from these large lift-pump motors to small motors for process drives.

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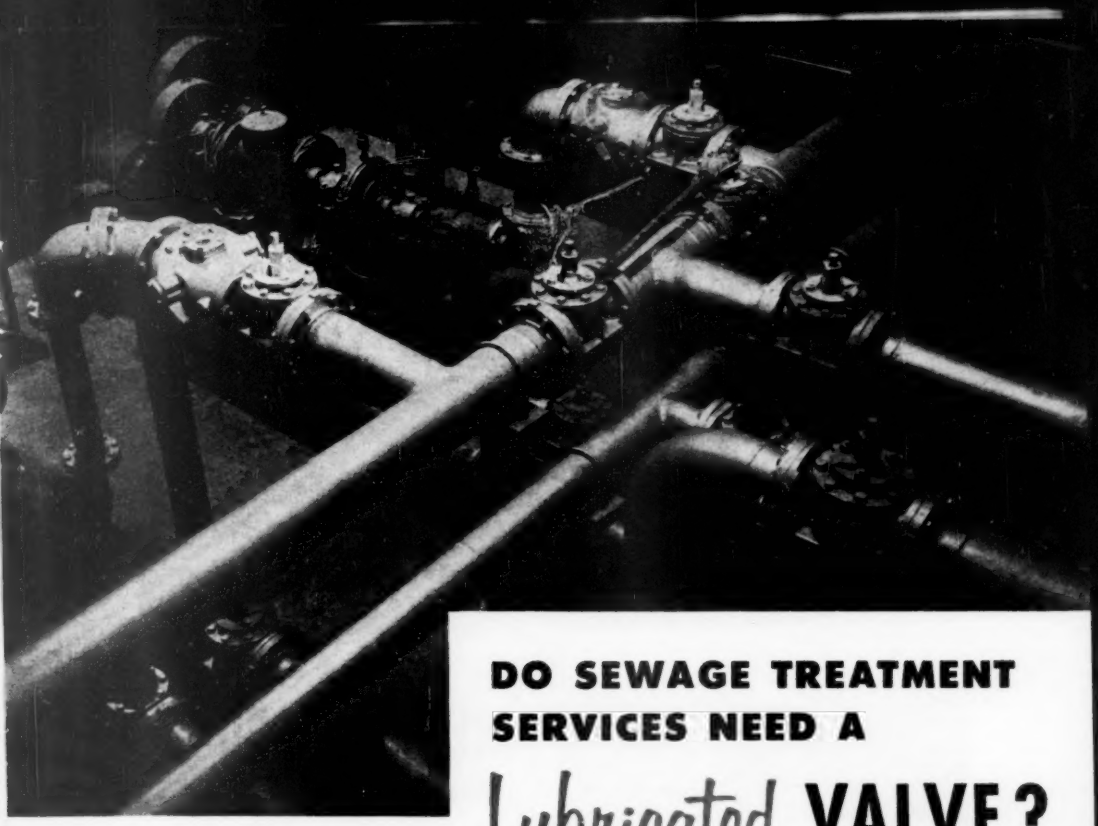
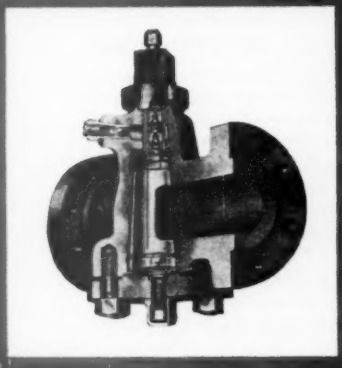


Nordstrom Lubricant-Sealed valves installed on sludge lines at a South Carolina sewage treatment plant.

THE NORDSTROM PRINCIPLE OF INTERNAL LUBRICATION



The body and plug of a Nordstrom valve are so constructed that lubricant-filled grooves surround seat port when the valve is in an open or closed position. This lubricant forms an impenetrable seal preventing flow of line fluid between plug and body. In addition to the lubricant-filled grooves, a thin film of lubricant completely covers contact surfaces of plug and body allowing the plug to seat easily within the body without abrasive friction.

When necessary, the film of lubricant covering contact surfaces and the supply of lubricant in the grooves can be instantly replenished by a simple turn of the lubricant screw.

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Occasionally you'll find someone who thinks that because pressures and temperatures are not so high in sewage treatment plants as in other industries, a non-lubricated valve can do the job as well as a Nordstrom. Is this so? Definitely not!

A Nordstrom Lubricant-Sealed valve on *any* type of sewage treatment service has many advantages that can't be duplicated by a non-lubricated valve. Here are a few:

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2. Seat ports are completely surrounded by lubricant-filled grooves. Lubricant acts as a seal *preventing leakage* whether the valve is opened or closed.
3. A Nordstrom *lasts longer* than non-lubricated valves, because any mechanism of moving metal parts needs lubrication to prevent friction.
4. A Nordstrom is always ready to operate with a quick quarter-turn. The plug glides on a film of lubricant permitting *effortless, instant operation.*

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ROCKWELL Built Nordstrom Valves

Lubricant-Sealed for Positive Shut-Off

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is the REX® TOW-BRO Way to improved sludge removal

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Tow-Bro's *gentle suction* gives these important advantages:

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2. Greater Solids Concentration . . . Tow-Bro principle assures much higher solids concentration than is obtainable with conventional scraper-type mechanisms.

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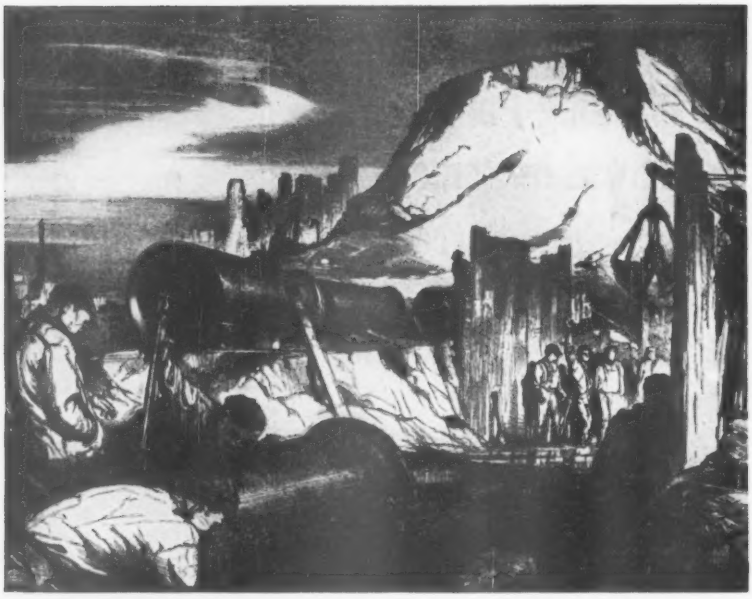

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 25 | January, 1953 | Number 1

Contents

Sewage Works

Studies of Sedimentation Basin Design. By THOMAS R. CAMP 1
Discussion by ALFRED A. ESTRADA 12
Chemical Structure and Action of Synthetic Detergents. By W. R. GOWDY 15
Anionic Syndets in Amsterdam Sewage. By P. N. DEGENS, JR., H. VAN DER ZEE, AND J. D. KOMMER 20
Algae Symbiosis in Oxidation Ponds. II. Growth Characteristics of *Chlorella pyrenoidosa* Cultured in Sewage. By WILLIAM J. OSWALD, H. B. GOTAAS, HARVEY F. LUDWIG, AND VICTORIA LYNCH 26
Design Factors of the Cleveland Southerly Sludge Heater Installation. By FRANK S. PALOCSAY 38

Industrial Wastes

Treatment of Finishing Process Wastes at the Ternstedt Instrument Plant. By A. W. SUNDWICK AND J. S. DELOS 44
Application of Biological Methods in the Treatment of Radioactive Wastes. By C. C. RUCHHOFT AND L. R. SETTER 48
Inoculation Studies in B.O.D. Determination on Sewage and Pulp Mill Waste. By RAYMOND ZEHNPFENNIG AND M. STARR NICHOLS 61
Color in Industrial Wastes. IV. Effect of Light on Certain Wastes. By WILLEM RUDOLFS AND WILLIAM D. HANLON 66
White Water Treatment. V. Aeration with Nonflocculent Growths. By WILLEM RUDOLFS AND HERMAN R. AMBERG 70

Stream Pollution

Biological Effects of Pollution in Michigan Waters. By EUGENE W. SURBER 79

The Operator's Corner

Up-to-Date Job Appraisals 87
Job Analysis and Evaluation in the Classification of Jobs. By J. J. WOLF 88
Operation Kinks at the Gowanda, N. Y., State Hospital Sewage Plant. By WILLIAM L. EDWARDS 92
Interesting Extracts from Operation Reports: Aurora, Ill.; Detroit, Mich. 95
Flush Tank Used to Prevent Sewer Freezing. By EDWIN M. LAMPHERE 100
Tips and Quips 102

Federation Affairs

Twenty-Fifth Annual Meeting Report 104
Special Report on Sanitary Engineering Salaries. By EARNEST BOYCE AND W. H. WISELY 10

Reviews and Abstracts 114

Proceedings of Member Associations

California Sewage and Industrial Wastes Association 22a
Louisiana Conference on Water Supply and Sewerage 24a
Central States Sewage and Industrial Wastes Association 26a

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Sewage Works

STUDIES OF SEDIMENTATION BASIN DESIGN *

By Thomas R. Camp

Camp, Dresser & McKee, Consulting Engineers, Boston, Mass.

In the treatment of water, sewage, and industrial wastes, sedimentation is more widely used than any other major process. No doubt it is the oldest process which has remained in continued use throughout the years. Despite the importance of the process and the long years of experience in its use, sedimentation basins continue to be built with little or no attention to functional design. The dimensions of most settling tanks are fixed on the basis of standard detention periods recommended by state health departments. This practice prevails in total disregard of the fact that evidence was presented nearly 50 years ago that removal of suspended matter by settling depends upon the floor area of the tank and not upon the tank volume.

A cardinal principle in the functional design of sedimentation basins is to provide sufficient floor area to receive the particles to be settled out. This principle was first announced to the sanitary engineering profession by Hazen (1) in 1904. The purpose of this paper is to explain this principle again in simple terms and to present other principles (2) which determine the shape of sedimentation basins for best performance of their function.

Overflow Rate *vs.* Detention Period

Particles of suspended matter will fall or rise through a fluid depending upon whether they are heavier or lighter than the fluid. For example, most suspended particles in sewage will settle downward, whereas grease, which is lighter than water, will rise and form a scum on the surface. For simplicity this discussion is confined to particles heavier than water. The principles, however, are the same whether a particle falls or rises.

A suspended particle in a dilute suspension will settle at a constant velocity with respect to the liquid immediately surrounding the particle so long as the particle maintains its individuality and does not change in size, shape, or density, and as long as the temperature of the liquid does not change. This constant velocity is called the settling velocity of the particle. If the suspended particle coalesces with another particle, as is the case in coagulation which prevails in most sedimentation processes, the resulting larger particle will settle at a greater velocity than the settling velocity of either of the smaller particles from which it was formed. Thus, coagulation—or flocculation, as it is frequently called—results in more rapid clarification.

Figure 1 represents an idealized picture of a sedimentation basin of the rectangular, horizontal, continuous-flow type. The longitudinal section through the basin shows four zones—the inlet zone, in which the suspension is distributed over the cross-sectional area of the basin; the settling zone, in which effective sedimentation takes place; the outlet zone, in which the clarified suspension is collected and discharged to the effluent flume; and

* Presented at 1952 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; August 27–29, 1952.

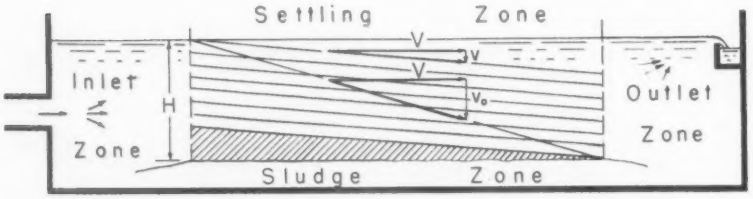

FIGURE 1.—Zones of a rectangular, horizontal, continuous-flow sedimentation basin.

the sludge zone, which is provided for collection of sediment under the settling zone and may be neglected in many primary settling tanks employing continuous sludge removal. For simplicity it is assumed that the water velocities are horizontal and the same throughout the settling zone, the magnitude of the water velocity being designated by V.

Consider a suspension of discrete particles, each of which has the same settling velocity, v. These particles will traverse paths through the settling zone indicated by the light parallel lines, the direction of which is the vector sum of the tank velocity and the settling velocity of the particles. Those particles which enter the settling zone near the bottom will traverse paths within the shaded area and will settle out. All particles which enter the settling zone above the shaded area will pass out of the settling zone into the outlet zone and may be carried upward over the effluent weir. If, now, the settling velocity of the particles is equal to or greater than v_o it is obvious from the figure that they would all reach the bottom and be removed from the liquid. It is evident from similar triangles that the removal ratio of particles having a settling velocity v is equal to v/v_o. In Figure 1, about a third of the particles will be removed.

Suppose the process illustrated by Figure 1 is changed by the construction of an intermediate tray at one-half the depth H, with no other changes. The velocity of the water in the tank has not been changed, and the settling velocity of the particles remains the same. The maximum depth through which the particles have to settle, however, has been reduced by one-half, and there is twice as much floor area upon which the particles may settle. There are now two shaded areas (Figure 2) which contain the paths of particles which will be removed. In the particular example illustrated by Figures 2 and 1, the removal ratio has been doubled by providing twice the floor area. The rate of discharge and the detention period are the same for Figures 1 and 2. Nevertheless, the removal, with the intermediate tray as shown in Figure 2, is twice as great as it is in Figure 1.

Now, suppose that for the same rate of discharge and the same particles to be settled out, the tank of Figure 1 is reduced to one-half its original depth, as indicated in Figure 3. The tank velocity in this case will be 2 V. Because of the increased tank velocity,

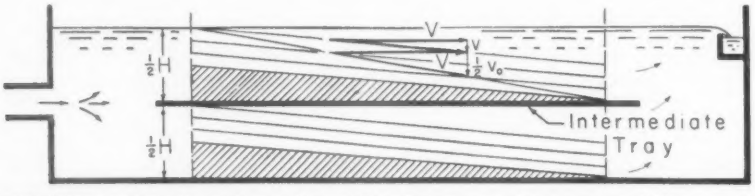

FIGURE 2.—Tray in tank provides added floor area and increases solids removal.

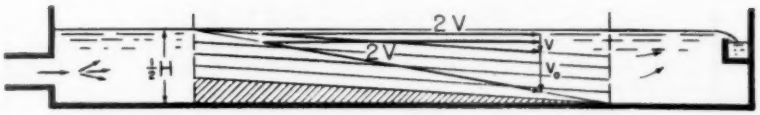

FIGURE 3.—Reduced tank depth does not increase removal ratio.

all particles will settle along paths which will have half the slope of the corresponding paths in Figure 1. Hence, the removal ratio will be the same as for Figure 1. In other words, the removal is independent of the depth of the tank in this idealized case. The depth of the tank may be increased or decreased at will without having any effect on the removal ratio. For economy it is obviously desirable to make the depth the minimum practicable. In design, the minimum practicable depth is determined by the space requirements for sludge removal equipment or the necessity of avoiding scour of the deposited sludge.

The settling velocity v_o of particles which would barely be removed in an idealized tank if they entered the settling zone at the surface, is known as the overflow rate of the tank. This settling velocity may also be thought of as a rate of discharge per unit of surface area of the settling zone or per unit of floor area. Overflow rates in common use for primary sedimentation of sewage range from about 200 to about 1,000 g.p.d. per square foot.

Figures 1, 2, and 3 illustrate typical free-settling processes such as take place in the primary sedimentation of sewage or in secondary sedimentation following trickling filters. The settling of the mixed liquor in the activated sludge process is not a typical free-settling process. The process consists primarily of compaction of the sludge blanket, which may occupy a considerable portion of the depth of the tank. Even so, final settling tanks for the activated sludge process should be designed on the basis of overflow rates rather than detention periods, with due allowance being made for the depth to be occupied by the sludge blanket. Overflow rates in common use in final settling tanks of the activated sludge process range from about 1,000 to about 3,000 g.p.d. per square foot.

Effects of Flocculation and Turbulence

The flow in the settling zone of an actual sedimentation basin is not as simple as is depicted in Figures 1, 2, and 3. In the first place, the velocity is not constant over the cross-sectional area, even under the best of conditions, being zero at the walls and floor, and having a maximum value near the center of the tank and near the water surface. There is, moreover, turbulence in the flow, consisting of eddies, which may carry some particles upward and some particles downward at faster velocities than the settling velocity of the particle. There is also the effect of flocculation of the particles during settling.

Flocculation in a sedimentation basin is due to two causes: (a) differences in the settling velocities of particles, whereby faster settling particles overtake those which settle more slowly and coalesce with them; and (b) velocity gradients in the liquid, which cause particles in a region of higher velocity to overtake those in adjacent stream paths moving at slower velocities. The first of these causes is illustrated in Figure 4, in which particle A, with a higher settling velocity than particle B, overtakes particle B and coalesces with it, after which the larger particle, comprising both A and B, settles along a steeper path.

For simplicity of illustration it has been assumed in Figure 4 that the tank velocity is the same throughout and that there is no turbulence. It may be

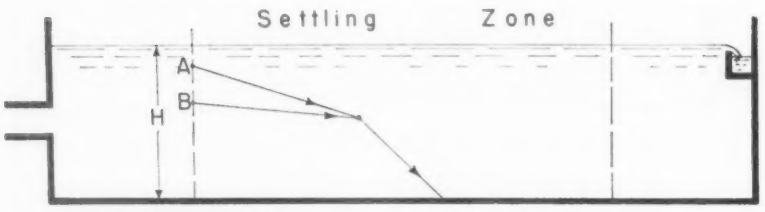

FIGURE 4.—Effect of particle agglomeration on settling.

seen now that if the depth is decreased for the same rate of discharge, the tank velocity V will be proportionately increased, and the slopes of the paths of the three particles will be proportionately decreased. Thus, particles A and B will coalesce at the same distance from the inlet end of the settling zone and the resulting larger particle will reach the bottom at the same distance from the inlet zone. It is evident, therefore, that flocculation due to differences in settling velocities of particles is not affected by the depth of the tank.

Velocity gradients (3) in the tank are caused primarily by eddies resulting from turbulence. It has been demonstrated (2) that the rate of flocculation due to the mean velocity gradient in a rectangular sedimentation basin is inversely proportional to the square of the depth of the settling zone. Hence, flocculation due to turbulent eddies will be greater in shallow tanks. Since flocculation promotes removal of suspended matter, shallow tanks are obviously preferable to deep tanks, provided, of course, they are not shallow enough to permit scour of settled solids.

Figure 5 illustrates in the idealized tank the effect of turbulent diffusion on sedimentation. The straight line with the arrow illustrates the path that would be taken by all particles with a settling velocity equal to the tank overflow rate which enter the settling zone at the water surface, provided, however, there is no turbulence and the tank velocity is the same throughout the settling zone. If turbulence is superimposed on this flow pattern, some of the particles will diffuse upward and some will diffuse downward, such that all of the particles with this same settling velocity will be contained within an envelope such as is shown by the broken curved lines. Some of the particles will reach the bottom sooner than without turbulence, but others will be carried out in the effluent. The net result of turbulent diffusion is to decrease the removal.

Dobbins (4) studied the effect of turbulence on the removal of discrete particles in sedimentation about 10 years ago and derived equations for computing the effect. Figure 6 is a dimensionless graph (2) prepared from Dobbins' equations. The symbol ϵ appearing in the horizontal scale of values is the mixing coefficient of turbulent flow theory. The value of $v\,H/2\epsilon$ is approximately equal to $122v/V$.

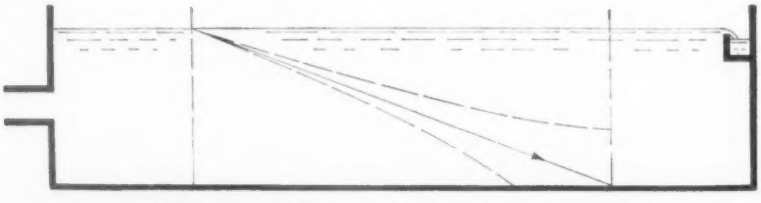

FIGURE 5.—Effect of turbulent diffusion on settling.

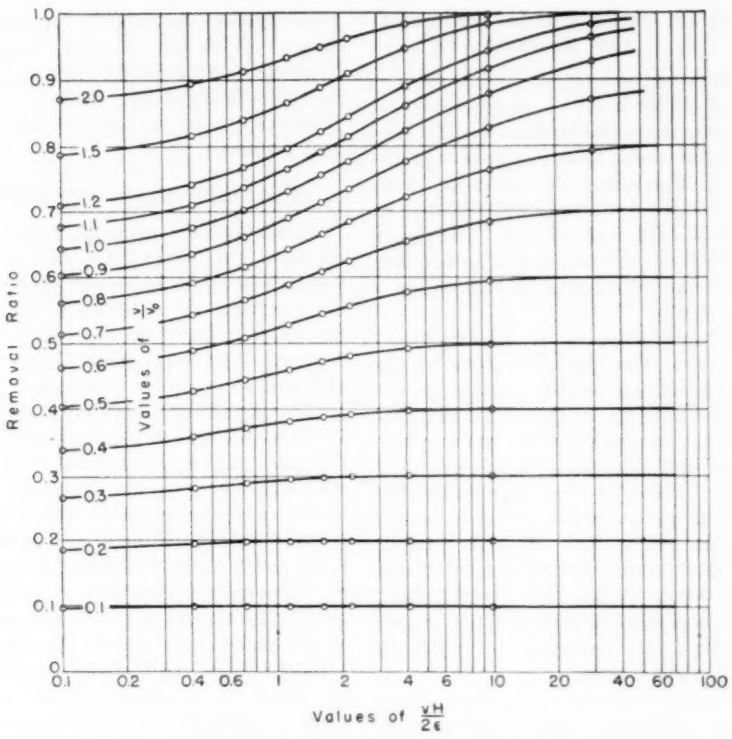

FIGURE 6.—Effect of turbulence on removal ratio.

In other words, the values on the horizontal scale of Figure 6 increase as the tank velocity decreases.

A study of Figure 6 indicates that turbulence in tanks with low velocity has relatively little influence on the removal ratio for most suspensions dealt with, but that the influence is appreciable in tanks of high velocity. This figure has been quite useful in predicting the removal of grit in the design of grit chambers. In this case the particles dealt with are discrete and little flocculation occurs. The graph may be used to indicate roughly what the effect of turbulent diffusion will be in primary sedimentation basins.

It is evident from the foregoing discussion that the removal of suspended matter in a sedimentation basin is unaffected by the depth of the tank except through the influence of turbulence and bottom scour. Turbulence, which increases as the tank velocity is made larger, retards removal by turbulent diffusion and also increases removal by promoting flocculation. In primary sedimentation basins, it is probable that flocculation more than compensates for retardation of removal by turbulent diffusion. The tank velocity in conventionally designed sedimentation basins is generally less than 3 ft. per min. There is evidence that velocities as high as 12 to 18 ft. per min. may be used in properly proportioned basins without scour of sludge from the bottom of the basin. Thus, the limitations of sludge scour are not critical and permit the use of much shallower tanks than is common in practice.

Optimum Dimensions for Sedimentation Basins

When sedimentation basins are designed on the basis of detention period without due consideration to the performance needs, there is a great temptation to dimension the tanks so as to produce the required tank volume at the least construction cost. This leads inevitably to circular tanks and square tanks, which are numerous throughout the country.

The performance of square tanks and radial flow circular tanks in the removal of suspended matter is extremely poor as compared to the performance of long, narrow rectangular tanks with the same volumetric capacity. There are two reasons for the deficient performance of such tanks: (a) the size of the effective settling zone is reduced because the inlet and outlet zones occupy too great a part of the total path of flow, and (b) short-circuiting and instability of flow prevail in short tanks.

It has been found by hydraulic laboratory experiment that with the very best design of inlet and outlet devices, the inlet zone and the outlet zone will each occupy a portion of the length of the path of flow at least equal to the depth of the tank. There is, of course, some settling in these two zones, but because of the turbulence and upward currents it is safer to neglect this settling in tank design and assume that all settling occurs in the settling zone. In most conventionally designed radial flow tanks, there would be little settling zone left if proper allowance is made for inlet and outlet zones. On the other hand, if a tank is designed as a long rectangular tank, with a length 20 or more times the depth and width, the inlet and outlet zones will occupy only about 10 per cent of the length of the tank, and the settling zone will occupy about 90 per cent. With short tanks, it is extremely important that inlets and outlets be designed so as to conserve as much of the tank capacity as possible for sedimentation. With long narrow tanks, the importance of inlet and outlet design becomes insignificant because of the relatively small size of the inlet and outlet zones.

Short-Circuiting and Stability

It has become common practice to measure the short-circuiting characteristics of tanks by introducing a slug of dye, salt, or radioactive tracer at the inlet end and measuring the concentration of the tracer at the tank outlet after various intervals of time following the introduction of the slug. If all of the tracer could pass through the tank at the nominal tank velocity, the entire slug would appear at the outlet at the same time. This time of passage, called the detention period, is equal to the volume of the tank divided by the rate of discharge. Actually, however, some of the tracer will appear at the outlet in much less than the detention period and some remains in the tank for a much longer period. Figure 7 illustrates the shapes of the concentration-time curves for various types of tanks, as measured in models and in full-scale tanks.

Figure 7 is a dimensionless plot with the horizontal scale in terms of the ratio of the actual time a certain concentration appears at the outlet to the detention period for the tank. The vertical scale is in terms of the ratio of the actual concentration of the tracer to the concentration which would obtain if the tracer slug were mixed instantaneously with the entire contents of the tank.

Curve A is the theoretical curve for an ideal dispersion tank in which the slug is mixed instantaneously with the tank contents. The short-circuiting characteristics of actual mixing chambers where the mixing is violent, approximate curve A quite closely, except that it takes a short time even in such tanks for the first appearance of the tracer at the outlet. Curve B is char-

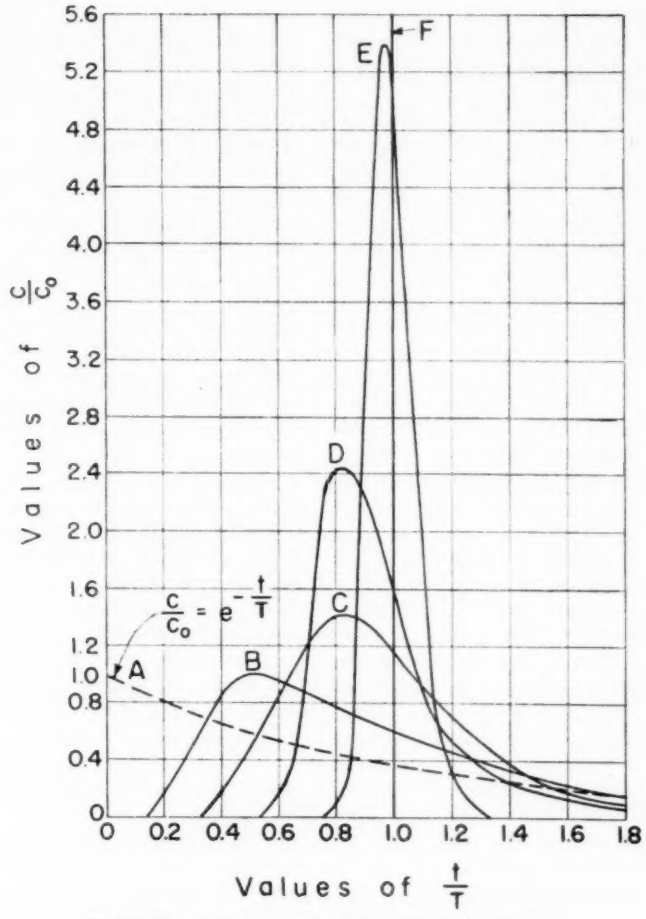

FIGURE 7.—Typical dispersion curves for tanks.

acteristic of radial flow circular tanks under stable flow conditions. Curve C is characteristic of wide rectangular tanks with relatively shallow depth. Curve D is characteristic of long, narrow rectangular tanks, and Curve E is characteristic of round-the-end baffled mixing chambers, very long, as compared to width and depth. The vertical line at F represents what would take place in an idealized tank such as represented by Figures 1, 2, and 3.

Curve B indicates that some suspended matter may be expected to reach the outlet of a radial flow circular tank in about 15 per cent of the detention period, and the greatest concentration of suspended matter may be expected to reach the outlet in about one-half the detention period. On the other hand, Curve D indicates that none of the suspended matter will reach the outlet of a long, narrow rectangular tank in less than one-half the detention period, and that the highest concentrations of suspended matter will remain in the tank for about 80 per cent of the detention period. Since removal by settling is a function of the time allowed for set-

tling to take place, it is obvious that long, narrow rectangular tanks are vastly superior in performance to radial flow circular tanks.

Extensive hydraulic laboratory experiments on models of tanks indicate that it is very difficult to reproduce short-circuiting curves for radial flow circular tanks and for square tanks. The flow patterns in such tanks are quite unstable and are easily affected by convection currents and density currents. On the other hand, the short-circuiting characteristic curves for long, narrow rectangular tanks can be reproduced quite faithfully. The flow pattern in the long tank is quite stable because sufficient length is provided to develop a stable flow pattern through the drag on the walls and floor of the tank.

If it is desired to minimize short-circuiting effects in a sedimentation basin, the basin should be covered so as to avoid the effects of both sun and wind. Vertical convection currents may be induced by the action of the sun, whereas horizontal surface currents of considerable magnitude may be induced by wind. In an open pond, surface water currents may be induced by wind action with velocities from 1 to 3 per cent of the wind velocity. Thus, a 5-m.p.h. wind can induce a surface current with a velocity of 4 to 12 ft. per min. Since these velocities are of the same order of magnitude as tank velocities, it is obvious that serious short-circuiting may be induced by wind.

Preflocculation for Primary Sedimentation

In nearly all large modern sewage treatment plants and in most waste treatment plants, the suspension is pumped before it enters the primary sedimentation basins; and in most sewage plants the suspension is screened and metered before being settled. All of these preparatory processes introduce high velocity gradients in the liquid which are destructive of flocculent particles. Experimental evidence was produced by Fischer and Hillman (5) about 12 years ago that 20 min. of self-flocculation of raw sewage prior to settling increases the removal of suspended solids during 60 min. of settling by 4 to 36 per cent over results obtained without flocculation, an average improvement of 20 per cent. In studying the flocculation and settling of iron floc for water treatment, Root (6) found that with a total time of mixing and quiescent settling in excess of 75 min., any increase in mixing time at the expense of settling time, up to 60 min. of mixing, would improve the settling. It is obvious, therefore, that preflocculation prior to primary settling is extremely important.

Preflocculation as an adjunct to primary treatment of sewage has been badly neglected, except in cases where chemical coagulation is used, or in cases where pre-aeration is used. Even in these cases, moreover, the value of the preflocculation is to some extent destroyed because the flocculation tanks are not constructed as an integral part of the sedimentation basins. Once the floc is formed, it should be handled gently until it is settled. The passage of a flocculent suspension through connecting conduits at high velocity subjects the particles to high velocity gradients, which shear them apart.

Experience indicates that good floc formation takes place in chemical coagulation processes with mean velocity gradients ranging from about 5 up to about 75 ft. per sec. per foot. Fragile floc once formed should not be subjected to velocity gradients much in excess of those to which it was subjected when it was formed. If a velocity gradient of 75 ft. per sec. per foot is accepted as the maximum permissible to avoid destruction of a particular kind of floc in connecting pipelines, computations indicate that at 50° F. the upper limiting velocity for

12-in. pipe is about 2 ft. per sec., for 48-in. pipe is about 3.2 ft. per sec., and for 10-ft. pipe is about 4.3 ft. per sec. To minimize the possibility of floc destruction in passage from flocculation chambers to sedimentation basins, the flocculation chambers should be built integrally with the sedimentation basins with a relatively large opening through the wall between the two.

In large sewage treatment plants, it is necessary to have a large number of primary settling tanks in parallel. One of the hydraulic problems in the design of such a plant is to distribute the suspension effectively from the inlet conduit to the parallel sedimentation basins. It is not economically practicable to obtain perfect distribution so that each basin has the same rate of discharge. In design a maximum difference in rate of discharge which is acceptable may be adopted, and the distributing conduits designed to conform therewith. This is accomplished by taking a relatively large head loss at the inlet to each basin as compared to the difference in head available from the connecting conduit between the most distant tanks. To accomplish reasonably uniform distribution of flow by this method, a relatively high velocity is required at the inlet to each tank. These velocities are much too high to preserve floc if preflocculation has been accomplished in a separate set of tanks. If preflocculation is accomplished in flocculation basins built integrally with the sedimentation basins, however, the high inlet velocity required for distribution between the tanks is at the inlet end of the flocculation chambers and does no harm.

Suggested Types of Settling Tanks

To adapt currently available straight-line sludge removal equipment to long rectangular tanks, the depth of such tanks must be not less than about 5 ft. to accommodate the sprockets. Figure 8 shows a suggested design for primary tanks for sewage or water softening based on the use of currently available sludge removal equipment. This is a three-pass tank, with the first pass occupied by flocculating equipment. It is proposed to provide sludge removal

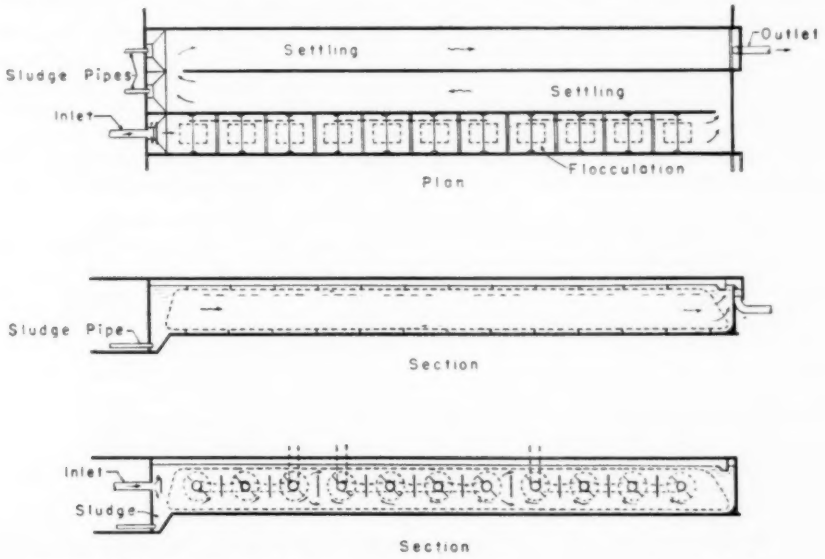

FIGURE 8.—Proposed design for primary tanks for sewage or water softening.

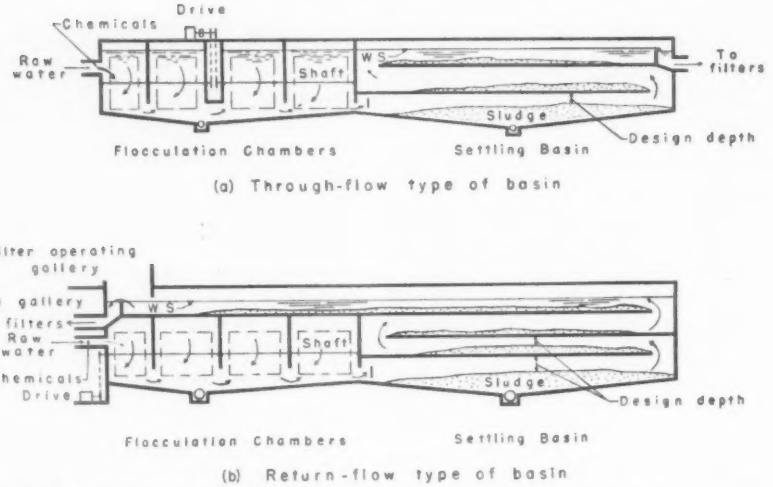

FIGURE 9.—Suggested design for primary tanks without mechanical sludge removal.

equipment even in the first pass. In all three passes sludge would be scraped towards the inlet end of the tank and scum towards the outlet end. Flocculation in the first pass may, of course, be accomplished by aeration as well as by mechanical stirring.

In most water treatment plants not involving softening, the rate of collection of sludge is not great enough to justify the use of mechanical equipment for removal. At intervals, the sedimentation basins are taken out of service and unwatered for sludge removal, and the sludge is flushed to the drains by hand hose or monitor nozzles. Figure 9 illustrates a suggested design (7) for basins of this type, in which the space between trays should provide sufficient head room for workmen during the sludge removal process.

At Cambridge, Mass., the old sedimentation basins constructed nearly 30 years ago, and having a water depth of 16 ft., have recently been remodeled (8) to provide two trays and flocculation tanks similar in type to Figure 9a. The basins are now in operation with excellent results. The construction of the trays provided settling capacity nearly three times that available in the old basin and avoided the con-

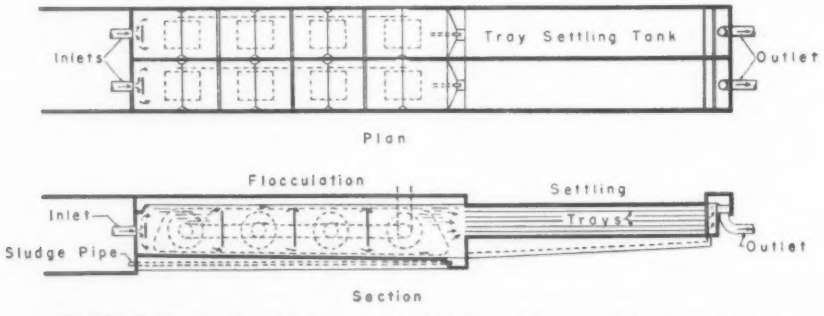

FIGURE 10.—Proposed primary tank design utilizing small-clearance trays.

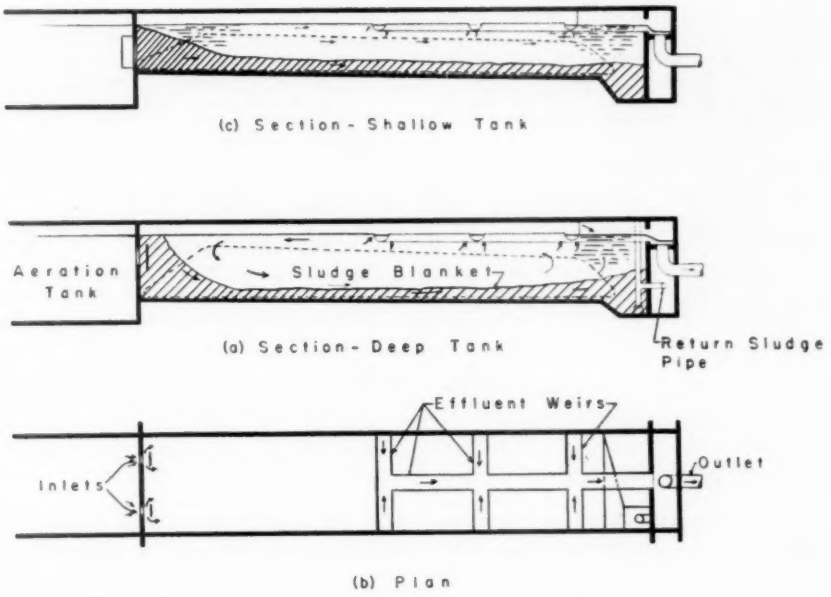

FIGURE 11.—Proposed final settling tank design for activated sludge.

struction of new sedimentation basins having double the capacity of the old basins. It is obvious that a very substantial saving in cost resulted.

Basins of the type shown in Figure 9 may be adapted for sludge removal equipment by installing a collector mechanism for each pass. Some large, modern water treatment plants have been constructed with a single tray and two passes. When two or more passes are provided, it is tempting to try to make a single collector mechanism serve two trays. This has been accomplished successfully at Chicago and at Los Angeles.

Figure 10 illustrates a proposed design for the primary settling of water or sewage which includes a multiple-tray settling tank with very small vertical clearances between trays. It is not now practicable to use such a settling basin, because no satisfactory sludge removal equipment has yet been developed for basins of this type. The functional advantages of such a basin are tremendous, however, and it is to be hoped that sludge removal equipment will be perfected in the not-too-distant future.

Figure 11 shows a desirable trend in the design of final settling tanks for the activated sludge process. Both Figures 11a and 11c show tanks equipped for the collection of sludge at the outlet end. Fig. 11a illustrates a relatively deep tank with the inlet near the water surface, which permits the mixed liquor to drop to the bottom of the tank and be carried as a density current at high velocity along the bottom. The arrows indicate the circulation produced above the sludge blanket by the density current. Fig. 11c illustrates a shallow tank with the inlet near the bottom so as to avoid the production of a density current.

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DISCUSSION

By Alfred A. Estrada

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Mr. Camp has made a very important contribution to the knowledge available for the better understanding of the principles involved in sedimentation. It is also interesting to note that the principle of sedimentation tank design based on bottom area, as propounded by Hazen almost 50 years ago, was not widely used until after 1930, when Mr. Camp started to preach the gospel of design by tank area rather than by tank volume.

This principle is now used as a measure of possible tank efficiency by most engineers charged with the design of sedimentation units in plants, either for treatment of sewage or water, as well as by health department engineers charged with the review and approval of these designs. However, the use of tank volume or detention is still used by many engineers and in many cases it is the governing criterion.

The Upper Mississippi River Board of Public Health Engineers and the Great Lakes Board of Public Health Engineers, represented by officials from 10 states, in January, 1951, published "Tentative Standards for Sewage Works Design."

These standards completely ignore detention periods in their design criteria on settling tanks and base their criteria on surface settling rates which vary according to type of tank (primary, intermediate, or final), and in final tanks according to type of treatment (such as trickling filter or activated sludge).

These standards also set the criteria for depth as follows:

"The depth of mechanically cleaned sedimentation basins shall be as shallow as practical but with a minimum water depth of 7 ft. Final clarifiers for activated sludge shall have a minimum water depth of 8 ft."

This certainly is recognition of the principles which Mr. Camp has been preaching.

The use of prefloceculation is of great value as an aid to sedimentation, as Mr. Camp has pointed out. In Pennsylvania, with its Clean Streams Program requiring the construction of so many sewage and industrial treatment waste plants, the use of this tool has not been neglected. Prefloceculation is either proposed in the design or already constructed in plants for Philadelphia, Pittsburgh, York, Lancaster, and many other places.

Multiple-tray tanks, as the author has stated, are gaining wider use in

the waterworks field. This type of tank is being used at Philadelphia, as well as at Chicago, Los Angeles, and Cambridge, Mass.

The use of this type of tank for sewage treatment, however, is open to serious question. Sludge which has once settled and turned septic will float to the surface, as shown by experience. Should this occur in a multiple-tray type tank, this sludge would be trapped under the tray and not be allowed to come to the surface for removal as scum or water sprayed for liberating entrapped gases and resettlement. Even if collectors were constructed in such a way as to scrape the underside of the tray, dragging the floating sludge along to an opening at the end of the tank, it is open to question as to whether the effluent from such a tank would not be much higher in B.O.D. than an open type of tank, because of accumulation of septic sludge and possible anaerobic environment.

In 1949, the firm of Albright & Friel was engaged to supervise pilot plant studies on a large food packing plant. Included in one of the schemes of treatment in the pilot plant were alternate studies on the efficiency of a conventional settling tank and a so-called "Dallas" or Uniflow settling tank. This type of tank has a sloping bottom, with the deep end at the influent and shallow end at the effluent. The conventional settling tank had a detention period of 85 min. and an overflow rate of 175 g.p.d. per sq. ft. based on the 2-g.p.m. rate through the pilot plant.

The suspended solids were reduced from 168.8 to 55.6 p.p.m. for a removal of 67 per cent.

The Dallas tank, on the other hand, had a detention period of 69 min. with an overflow rate of 182 g.p.d. per sq. ft. The tank varied in water depth from 10 in. to 16 in.

The suspended solids were reduced through the Dallas tank from 198.5 to 33.8 p.p.m. for a removal of 83 per cent, or 16 per cent more than the conventional type tank.

It should be noted, however, that the wastes treated in the two types of tanks were not divided flow from the same waste, but were waste waters from different types of vegetables, and that the suspended solids concentration in the influent was not the same. Therefore, the results could not be conclusive as to the relative merits of the two type tanks, although with 77 per cent of tank volume and about the same overflow rate, the suspended solids in the effluent were less in the Dallas type tank than in the conventional tank.

Conclusive results were obtained, however, in 1950 at Harvard University, when Thomas ran fresh sewage through parallel tanks with exact surface areas —one with a flat bottom or conventional type, and a second with a sloping bottom or Dallas type.

Thomas found that with the same overflow rate and 75 per cent of the conventional tank volume, the Dallas type tank removed substantially the same amount of suspended solids.

A study of the cross-section of the Dallas type tank raises the question as to whether a tank with a level bottom with a depth equal to about the average depth of the tanks tested would produce the same results as the Dallas type tank. These results tend to support the author's statement that the location of the bottom of the tank, within the limits of a scouring longitudinal velocity, has no effect on the efficiency of a settling tank.

It is understood from one equipment manufacturer who is studying this design, that no tanks of this type are in actual service. It also is understood that this type of tank will be incorporated into the construction of a sewage treatment plant by the Link-Belt Company at its new manufacturing plant at Colmar, Pa. This treatment plant is being designed for 90 g.p.m. The primary settling tank will be 10 ft. wide by 54 ft. long, with a water depth varying from 4 to 12 ft. It would be interesting if this tank could

be constructed first with a false relatively flat bottom with an average water depth of about 7 ft., so that results could be obtained on settling characteristics. Subsequent conversion of the tank to the Dallas type arrangement as now planned, would give conclusive results on a plant-scale basis as to the relative merits of the Dallas type tank *versus* shallow conventional type tanks.

In conclusion, the use of the overflow rate has been well established as the governing criterion for the design of sedimentation basins, due in no small measure to Mr. Camp's efforts.

THIRD QUARTER NPA WATER RESOURCES APPROVALS

Approval of 703 water and sewage construction projects with a total value of $343,025,641 in the third quarter of 1952 was announced recently by the National Production Authority, U. S. Department of Commerce. All of the projects were granted construction permits and received allotments of controlled materials.

Of the 703 construction jobs authorized, 450 were for waterworks and 253 for sewage. Water projects are valued at $215,570,241 and sewage construction at $127,455,400. These amounts include estimated cost of all materials, labor, and engineering, according to James C. Crenshaw, Director, Water Resources Division.

The volume of the water project jobs approved contrasts with 700 in the first quarter and 724 in the second. Authorized sewage applications also declined from 597 in the first quarter and 308 in the second quarter (see THIS JOURNAL, **24**, 4, 444; and **24**, 10, 1302: Apr. and Oct., 1952).

Controlled materials allotted by the Water Resources Division in the third quarter of 1952 totalled 125,000 tons of steel, 2,500,000 lb. of copper, and 130,000 lb. of aluminum.

New York headed the third quarter construction approvals with the greatest dollar value—$85,860,994—while California had the greatest number of projects approved. California's 116 approved jobs had an estimated aggregate cost of $41,446,605, whereas New York had a total of only 35 projects authorized. Ranking second in dollar value was Michigan, with $55,366,806 for 37 approved projects.

Copies of the detailed list of construction approvals, although not available for general distribution, may be inspected in the NPA Office of Public Information, Room 3K2, New General Accounting Office Building, Washington, D. C.

CHEMICAL STRUCTURE AND ACTION OF SYNTHETIC DETERGENTS*

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The widespread use of synthetic detergents by the American housewife in the last few years has been a subject of concern to some in the sewage disposal field, and there has been much speculation about the effects of synthetics on the operation of sewage treatment plants.

In this connection it should help to have a basic understanding of the various kinds of synthetic detergents, their properties, and how widely they are used. Actually, there are only two that are widely enough used to be important as far as content in domestic sewage is concerned, but questions have been raised about some of the others, even though they are not in widespread household use.

There are three kinds of synthetic detergents—anionics, where the active portion of the molecule is an anion; cationics, where the active portion is a cation; and nonionics, that do not ionize at all.

Anionic Compounds

By far the most commonly used washing products are anionics like those shown in Figure 1. The first structure in Figure 1 is a soap—in this case, the sodium salt of lauric acid that comes from coconut oil. Like any soap, it is simply a metallic salt of a straight chain fatty acid. Usually soap is made simply by boiling an oil or fat, such as coconut oil or tallow, with sodium hydroxide. In practice it is not really as simple as that, because care must be taken to get out all the extra sodium hydroxide over and above that needed for actual saponification. It is also a good idea, for economic reasons, to recover the glycerin free by the reaction. Finally, the "kettle soap" has to be processed into a more usable physical form.

The second molecule in Figure 1 is an alkyl sulfate—sodium cetyl sulfate. The "alkyl" sulfates were the first type of synthetic detergent to be commercially successful on the retail market. Originally a European development, it was first marketed in this country in 1934 as a dishwashing product, and immediately accepted because it did the kind of a job soap could do without the formation of lime soap or soap scum. It was quite a revolutionary step. Its structure looks a lot like that of soap, but its manufacture is considerably more complicated. Fats are first reduced to alcohols with metallic sodium. The alcohols are then reacted with sulfuric acid to form an intermediate fatty mono substituted sulfuric acid that in turn is neutralized with sodium hydroxide to give the kind of molecule shown in Figure 1. Other alkyl sulfates can be made starting with practically any aliphatic alcohol. Some of them are good detergents and some are not.

The third molecule in Figure 1 is an alkyl benzene sulfonate. The principle here is the same, except that a petroleum-derived alkylated benzene—instead of fat—is the starting material. It is reacted with sulfuric acid, to give a mono substituted compound. This, in turn, is neutralized with caustic soda, just as was the case with the alkyl sulfate.

The alkyl sulfates and alkyl aryl

* Presented at 1952 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

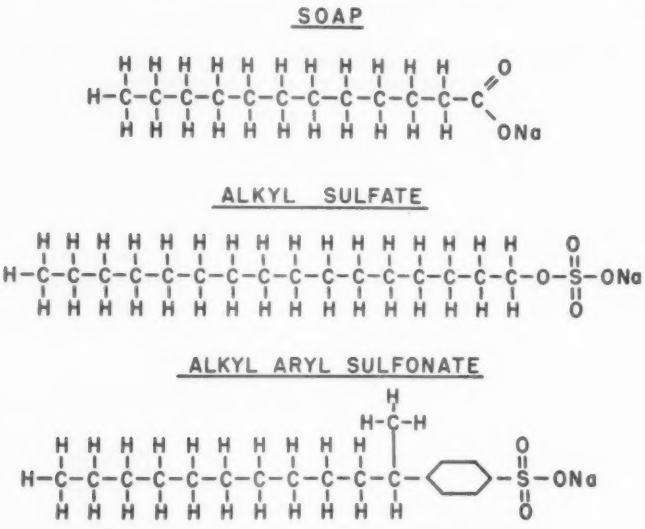

FIGURE 1.—Structure of typical anionic detergents.

sulfonates are by far the most common synthetic detergents in use today. They are the two that are used in the most popular detergents and represent by far the largest proportion of the synthetic detergents found in sewage.

The other two classes of synthetics are only a small portion of the detergents in household use, but they are of some interest nevertheless.

Nonionic Compounds

Synthetics of the type shown in Figure 2 are called nonionics, simply because they do not ionize. They are usually made by condensing some sort of fatty or oily material, here again an alkyl benzene, with several molecules of ethylene oxide. They are either liquids or waxy in physical form and tend to be sticky. As a result they are hard to put into the granule form that is so convenient to use.

Cationic Compounds

Figure 3 shows a typical cationic structure—one of the quaternary ammonium chlorides. As a class, they are not widely used for their washing ability. Some of them, however, are powerful germicides and are sold and used as such. There has been some speculation in the sewage works literature about what these materials might do to

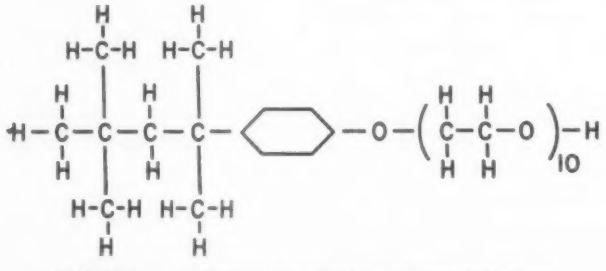

FIGURE 2.—Structure of a typical nonionic detergent.

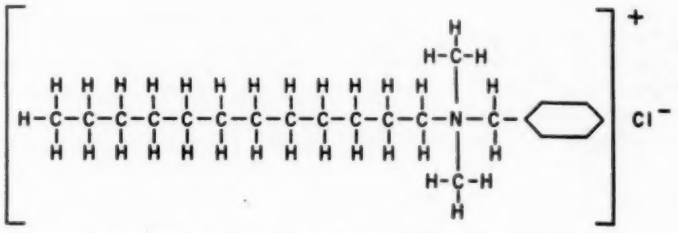

FIGURE 3.—Structure of a typical cationic detergent.

digestion processes. For that reason, they deserve some attention here.

Those cationics which are effective germicides are not compatible with the anionics—they cannot exist in the same solution in any appreciable amounts and keep their identity. The cationics react with the anionics and form compounds which are neither detergents nor germicides. As a result, those in use today cannot be used in ordinary household detergents because they do not keep their germicidal properties. By the same token, as long as there are anionics in sewage there should not be any reason to worry about any effects the cationics will have, because they will be neutralized by the anionics.

How Detergents Act

Figure 1 also shows the characteristic of detergent molecules which gives them their surface activity. In the case of soap and the alkyl and alkyl aryl sulfonates, one end of the chain is of a fatty nature. The other has a sodium ion with its usual characteristics of high solubility. Consequently, when these molecules are dissolved they become highly polarized.

Figure 4 represents the cross-section of a water solution of a detergent. The detergent molecules are represented by the little rods, showing how they act at an interface of water and some other surface. For instance, in Figure 4 they are surrounding two particles of foreign material. The tails represent the hydrocarbon portion that is trying to get as far away from water as possible, and the heads represent the sodium end that has a high affinity for water. The result of this polarity is that these molecules align themselves at every water interface. This action is what enables soaps and detergents to suspend dirt in washing dishes and clothes, and keep it from depositing back on dishes and clothes.

An important point to remember is that a suspending job cannot be done with very dilute solutions, if there is any appreciable amount of solids present to be suspended. Every particle of dirt that is suspended needs a great many molecules of soap or detergent to surround it and carry it, and keep it from agglomerating with other particles and either settling out or floating.

Another important fact to notice is that the free molecules which are unattached are the only ones that can form suds. The ones that are attached are unable to do it. If enough free molecules are available they can migrate to the air-water interface, where they can operate in the formation of

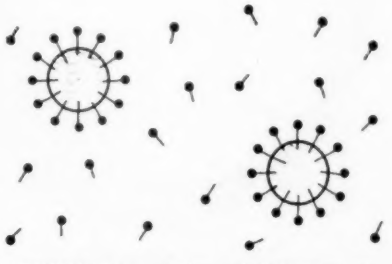

FIGURE 4.—Action of detergent at interface of water and dirt.

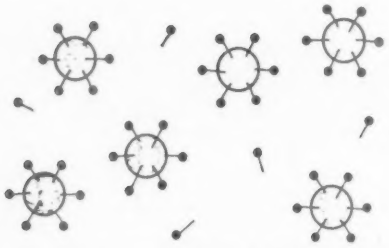

FIGURE 5.—Action of detergent on introduction of additional dirt to water solution.

suds. However, the air-water interface does not have enough attraction for them that they will remain there if there is soil present which has not already adsorbed a large number of these molecules. The soil or solids will preferentially adsorb detergent molecules so that when appreciable amounts of soil are present there will not be enough free molecules left at the air interface to allow sudsing. If the solution in Figure 4 has some more dirt added, the situation changes to that in Figure 5.

As shown in Figure 5, the detergent molecules have redistributed themselves among the particles that make up the increased load. As a result, they effect much less of a suspending force and there are far fewer free molecules to make suds.

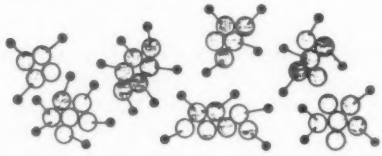

FIGURE 6.—Action of detergent on introduction of excessive dirt to water solution.

Figure 6 shows what happens when still more soil load is added than the amount of detergent present can handle. The detergent still tries to hold the soil, but it does not succeed, because there is not enough of it to

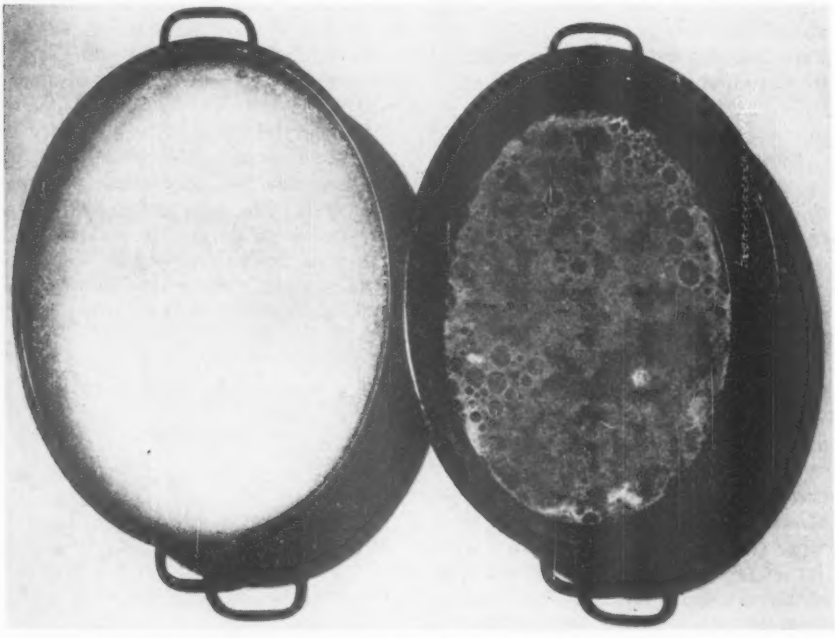

FIGURE 7.—Detergent suds before (left) and after washing dishes.

give good coverage to the tremendous surface area that has been created with the added soil. Also, when this happens there are no longer any free molecules left to create suds, and that is precisely why one runs out of suds in dishwashing or in the washing machine. The washing solution is so heavily loaded with soil that there is no longer any free detergent left to suds.

Figure 7 is a practical example of this. A dishwashing was done with a 3,000-p.p.m. solution of the leading household detergent. The dishpan on the left shows the panful of detergent solution before the start of the dishwashing. It has a good suds because anionic synthetic detergents are a lot like soap in their sudsing characteristics. A good suds under most circumstances means enough detergent is present to wash adequately. When there is not enough detergent to suds, there is not enough to wash. The pan on the right shows what was left after a dishwashing had been done with these suds. The detergent has all been "used up" by the soil so there is no longer any suds. It is evident how the high load has broken the emulsion. It is impossible to get any more suds out of such a solution no matter what is done to it short of adding more detergent. When there is more dirt than the suspending agent can handle, the whole emulsion and suspension just falls apart and the solution no longer suspends, cleans, or sudses.

Conclusions

These facts indicate that the extremely dilute concentrations of synthetics found in sewage can hardly alone be capable of causing frothing or settling problems. This conclusion has been supported by full-scale tests, as reported by Wells (1). Briefly, the tests involved controlled addition of synthetic detergent to the aeration tanks of an activated sludge plant, in amounts as high as 250 p.p.m. over and above that normally in the sewage. No frothing or other harmful effects were evident, even with such high concentrations. On the other hand, frothing could be created at will in the absence of added synthetic detergent by reducing mixed liquor solids to levels below 1,400 p.p.m.

Reference

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ANIONIC SYNDETS IN AMSTERDAM SEWAGE

By P. N. Degens, Jr., H. van der Zee, and J. D. Kommer

Koninklijke/Shell-Laboratorium; Publieke Werken, Afdeling Riolering en Waterverversching; and Koninklijke/Shell-Laboratorium, respectively, Amsterdam, Netherlands

About 90 per cent of the synthetic detergents now on the market are of the anion-active type (mainly alkyl sulfates and alkyl aryl sulfonates), the remainder being of the cationic and nonionic types. As a result, the study of the behavior of the two anionic types of synthetic detergents in the various steps of sewage purification should be given most attention.

For effective control of the concentration of synthetic detergents in raw sewage and in tank effluents it is essential that reliable analytical methods should be available. As far as is known, no methods are available for the determination of cationic and/or nonionic detergents in sewage.

For the determination of the total content of anionic synthetic detergents in sewage Evans (4) has suggested an extrapolation method based on the colorimetric methylene-blue method of Jones (5)(1). This extrapolation method, however, is still too much influenced by the possible presence in the raw sewage and tank effluents of nitrates, thiocyanates, and substances of the cholesterol type present in urine in the form of sulfate esters; besides, the method is not very suitable for routine analysis (6)(7). In cooperation with Evans and Winsor, the authors have therefore developed an improved version of the methylene-blue method, which, in addition, allows a separate determination of alkyl sulfate (the term in this sense including also other products that can be hydrolized in acid medium; for example, fatty acid amide sulfates) and of alkyl aryl sulfonate (in this sense also including the aliphatic sulfonates, or mersolates) detergents (3). Details of the method are given in the Appendix.

During the past year this analytical method has been used regularly for determining the presence of alkyl sulfate and alkyl aryl sulfonate anionic detergents in the raw domestic sewage of the Amsterdam sewage purification plants, which use the diffused air activated sludge process, with some trickling filters for emergency overloads.

The data on average 24-hr. samples from the West Amsterdam and South Amsterdam sewage treatment plants for the period from January, 1951, to June, 1952, are given in Table I. Figure 1 shows the hourly fluctuations in anionic detergent concentrations for a typical week, as determined by hourly samples from the West Amsterdam plant.

Table I shows that the total content of anionic synthetic detergents in Amsterdam raw sewage, as calculated over periods of six months, increases, and that this increase must mainly be attributed to the alkyl aryl sulfonate detergents. A survey summary of this increase is given in Table II, the maximum and minimum daily averages of anionic syndets in the Amsterdam raw sewage being given in Table III.

From Figure 1 it is evident that the concentrations of syndets in the raw sewage show diurnal fluctuations. As was to be expected, the concentrations are much lower in the morning hours than during the afternoon.

Since no definite judgment can yet be passed on the influence of synthetic detergents on sewage purification, it is

TABLE I.—Alkyl Sulfate and Alkyl Aryl Sulfonate Anion-Active Synthetic Detergents (in P.P.M.) in the Raw Sewage of Amsterdam (Jan., 1951–June, 1952)

Date	Raw Sewage, W. Amsterdam			Raw Sewage, S. Amsterdam		
	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total Anionic Detergents	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total Anionic Detergents
			(*a*) 1951			
Jan. 10	—	—	5.8	—	—	4.6
Jan. 24	—	—	5.3	—	—	5.0
Feb. 2	—	—	5.6	—	—	4.2
Feb. 21	—	—	3.9	—	—	3.3
Mar. 7	4.4	2.4	6.8	3.2	1.5	4.7
Mar. 21	4.9	1.4	6.3	3.8	1.0	4.8
Apr. 4	3.3	1.4	4.7	3.3	1.0	4.3
Apr. 18	4.8	1.1	5.9	3.1	0.8	3.9
May 2	5.0	1.2	6.2	3.5	1.0	4.5
May 16	3.8	0.9	4.7	4.0	1.0	5.0
June 13	4.5	1.8	6.3	3.8	1.0	4.8
July 11	1.4	3.0	4.4	1.6	1.4	3.0
July 25	2.3	3.6	5.9	2.9	1.3	4.2
Aug. 22	2.9	3.6	6.5	2.2	1.2	3.4
Sept. 20	4.6	3.9	8.5	3.1	1.4	4.5
Oct. 3	3.1	3.8	6.9	2.8	1.5	4.3
Oct. 17	2.4	4.0	6.4	2.3	1.6	3.9
Oct. 31	3.1	2.3	5.4	2.7	0.8	3.5
Nov. 14	2.8	2.4	5.2	3.3	1.0	4.3
Nov. 28	2.4	1.8	4.2	1.8	1.0	2.8
Dec. 13	6.2	1.0	7.2	4.1	0.7	4.8
			(*b*) 1952			
Jan. 7	4.0	2.0	6.0	3.3	1.4	4.7
Jan. 22	4.0	1.7	5.7	3.3	1.3	4.6
Feb. 13	3.5	2.3	5.8	3.0	1.1	4.1
Feb. 28	4.4	3.6	8.0	3.3	3.3	6.6
Mar. 14	3.6	6.2	9.8	3.1	3.9	7.0
Mar. 24	3.6	5.1	8.7	3.4	4.1	7.5
Apr. 1	4.4	4.9	9.3	4.2	3.6	7.8
Apr. 9	4.4	5.5	9.9	4.0	4.0	8.0
Apr. 17	4.8	5.5	10.3	4.6	4.9	9.5
Apr. 15	4.4	6.3	10.7	4.0	4.0	8.0
May 5	4.6	5.3	9.9	3.4	4.0	7.4
May 13	4.4	4.4	8.8	4.1	3.7	7.8
May 21	—	—	—	2.4	4.7	7.1
May 29	3.6	4.8	8.4	3.3	3.7	7.0
June 6	2.6	4.3	6.9	3.0	3.5	6.5
June 16	3.0	3.8	6.8	2.6	3.2	5.8

TABLE II.—Average Content (in P.P.M. of Active Matter) of Anionic Syndets in Amsterdam Raw Sewage

Period	West Amsterdam			South Amsterdam		
	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total Anionic Syndets	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total Anionic Syndets
First six months 1951	4.4	1.5	5.9	3.5	1.0	4.5
Second six months 1951	3.1	2.9	6.0	2.7	1.2	3.9
First six months 1952	4.0	4.4	8.3	3.4	3.4	6.8

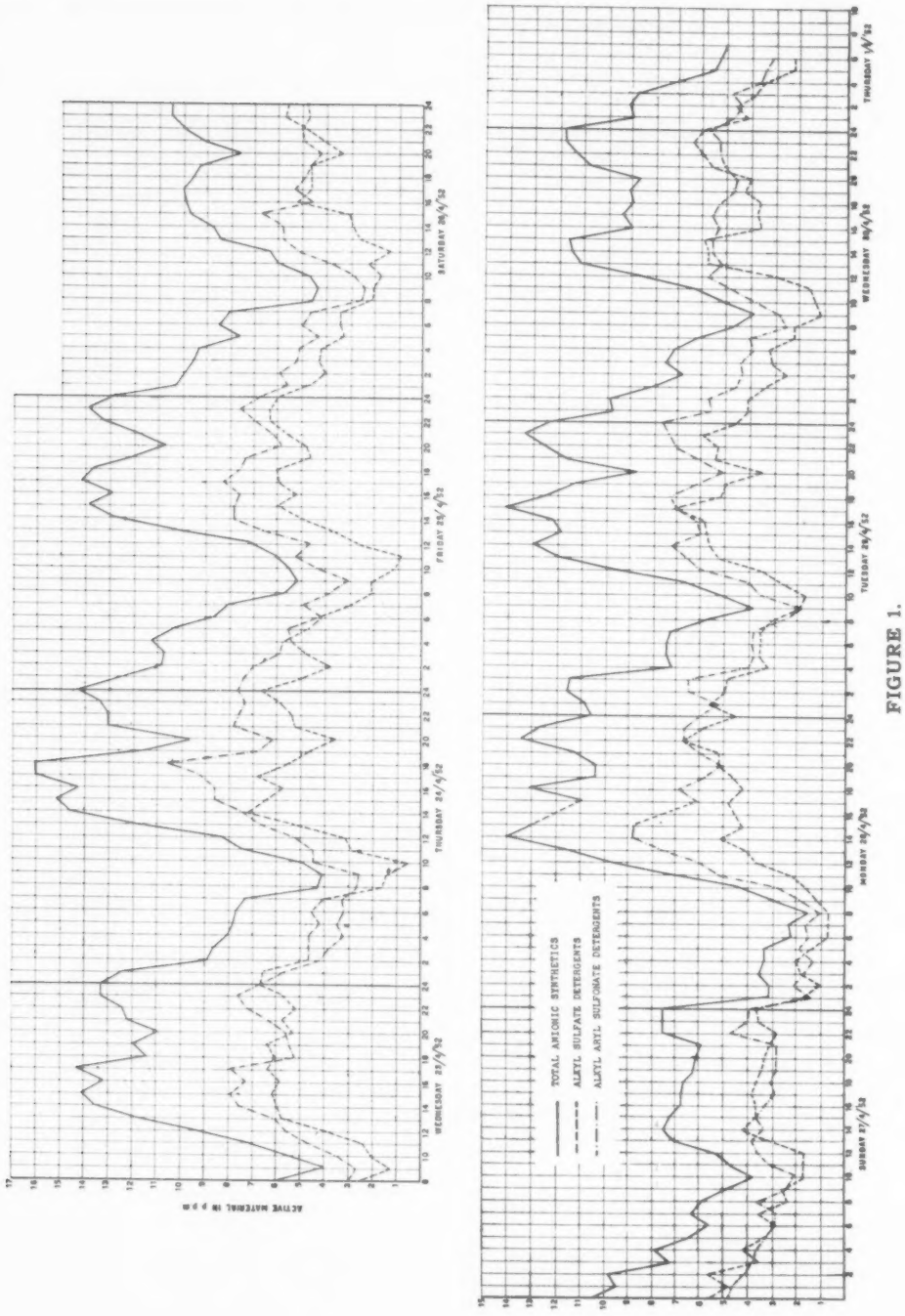
ACTIVE MATERIAL IN p.p.m.
WEDNESDAY 23/9/52
THURSDAY 24/9/52
FRIDAY 25/9/52
SATURDAY 26/9/52
SUNDAY 27/9/52
MONDAY 28/9/52
TUESDAY 29/9/52
WEDNESDAY 30/9/52
THURSDAY 1/10/52
TOTAL ANIONIC SYNTHETICS
ALKYL SULPATE DETERGENTS
ALKYL ARYL SULFONATE DETERGENTS

FIGURE 1.

TABLE III.—Maximum and Minimum Daily Averages of Anionic Syndets (in P.P.M. of Active Matter) in Amsterdam Raw Sewage

	1951		First Six Months 1952	
	Max.	Min.	Max.	Min.
(*a*) West Amsterdam				
Alkyl sulfates	6.2	1.4	4.8	2.6
Alkyl aryl sulfonates	4.0	0.9	6.3	1.7
Total anionic syndets	8.5	3.9	10.7	5.7
(*b*) South Amsterdam				
Alkyl sulfates	4.1	1.6	4.6	2.4
Alkyl aryl sulfonates	1.6	0.7	4.9	1.1
Total anionic syndets	5.0	2.8	9.5	4.1

important to discriminate between sulfate and sulfonate detergents.

Laboratory experiments have already shown that there is a distinct difference in biological conversion between alkyl sulfate and alkyl aryl sulfonate anionic detergents and nonionic detergents (2). These differences also have been observed during sewage purification in the West Amsterdam plant, as is evident from Table IV.

Acknowledgment

The authors wish to thank the management of the Koninklijke/Shell-Laboratorium and the management of the Amsterdam Public Works for their permission to publish this paper.

TABLE IV.—Anion-Active Synthetic Detergents (in P.P.M.) in Different Effluents of the West Amsterdam Sewage Plant

Sample[1]	January 29, 1952			January 30, 1952			January 31, 1952			April 15–May 1, 1952[2]		
	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total	Alkyl Sulfates	Alkyl Aryl Sulfonates	Total
Raw sewage	2.7	1.9	4.6	3.4	1.8	5.2	2.1	1.9	4.0	3.9	6.8	10.7
Settled sewage	3.0	1.5	4.5	3.3	1.3	4.6	2.5	1.1	3.6	—	—	—
Final effl., act. sl.	Nil	0.8	0.8	Nil	1.0	1.0	Nil	0.4	0.4	—	—	—
Final effl., tr. filt.	Nil	0.8	0.8	Nil	0.7	0.7	Nil	0.4	0.4	0.5	5.5	6.0

[1] 24-hr. samples.
[2] Average of 14 samples.

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APPENDIX—ROUTINE METHOD FOR DETERMINATION OF SULFATE AND SULFONATE ANION-ACTIVE SYNTHETIC DETERGENTS IN SEWAGE

The total anionic active material (sulfate + sulfonate) is determined by extraction of the methylene blue-detergent complex by means of chloroform and photoelectric estimation of the color intensity of the chloroform layer. The same procedure is repeated after acid hydrolysis, which yields the colorimetric value for sulfonate present.

Conditions of extraction must be adjusted so that possible interfering compounds (for example, nitrates, thiocyanates, and salts of steroid hydrogen sulfates) are not simultaneously extracted as methylene-blue derivatives by the chloroform. Cation-active synthetic detergents interfere in this method.

1. Apparatus

1.1. Photoelectric colorimeter. A sensitive photoelectric colorimeter equipped with a monochromatic light source, either a lamp with color filter or a monochromator capable of producing a light of narrow spectral range which is predominately orange (600 mμ.)

1.2. Separatory funnels, 250-ml.

1.3. Erlenmeyer flasks, 50-ml.

2. Reagents

2.1. Chloroform, c.p.

2.2 Methylene-blue solution, 0.035 per cent by weight of methylene blue (B.P. or U.S.P. grade) in 0.01N H_2SO_4.

2.3. Silver sulfate solution, 0.4 per cent by weight of silver sulfate, c.p., in distilled water.

2.4. Sulfuric acid, 96 per cent.

2.5. Sulfuric acid, 5N.

2.6. Sodium hydroxide, c.p., in pellets.

2.7. Hydrogen peroxide, 30 per cent by weight.

3. Procedure

Standardization

3.0. Prepare a master solution of a standard sample of an anion-active synthetic detergent (mol. wt. about 300) and analyze aliquots of this solution by the procedure described in 3.1. Make up a calibration curve. Compare the results of the analysis of unknown samples with the data obtained on the standard sample.

Total Content of Anion-Active Synthetic Detergent

3.1. Pipet 10 ml. of the sample into a 250-ml. separating funnel. Add 1 ml. H_2SO_4 (5N), 100 ml. of distilled water, 5 ml. of the methylene-blue solution, and 10 ml. of chloroform. [Note: If the sample contains thiocyanates > 5 p.p.m. as CNS and chlorides < 300 p.p.m. as Cl, add also 1 ml. of the silver sulfate solution before diluting the sample with 100 ml. of distilled water, etc. If the sample contains thiocyanates > 5 p.p.m. as CNS and chlorides > 300 p.p.m. as Cl, the thiocyanates should first be oxidized. After acidifying the 10-ml. sample with 1 ml. 5N H_2SO_4, add 1 ml. of 30 per cent H_2O_2 and let stand at room temperature (20° to 30° C.) for 10 to 15 min., and then dilute with 100 ml. of distilled water, etc.]

3.2. Shake gently (about two up and down movements per second) for 1 min. Allow to stand for some minutes. If necessary, stir the chloroform layer with an iron wire to break the emulsion, then separate the chloroform from the water layer. (If the emulsion does not break, centrifuge the emulsified layer.) Filter the chloroform layer through cotton wool into a 50-ml. standard flask. Repeat this extraction

twice with 10 ml. of chloroform and after the third extraction make up to volume accurately by adding chloroform through the cotton wool. Place the colored chloroform solution in the photometer cell and determine the instrument reading. Compare this reading with the calibration curve to determine the amount of extracted detergents (in p.p.m.) Make a blank determination according to the above procedure.

Content of Sulfonate Anionic Detergents

3.3. Pipet another 10 ml. of the sample into a 50-ml. Erlenmeyer flask. Add 1 ml. of concentrated sulfuric acid (98 per cent) and reflux for 1 hr. Add 1 drop of phenolphthalein solution, neutralize with NaOH pellets (about 10 to 12 pellets) to the phenolphthalein end point, and then acidify with 5N H_2SO_4 until acidity has just been reached. Cool and proceed as described under 3.1. and 3.2.

Content of Sulfate Anionic Detergents

3.4. This content is found by determining the difference between the total detergent content (3.1. and 3.2.) and the sulfonate detergent content (3.3.)

Repeatability

3.5. Duplicate analyses may not differ by more than 0.5 p.p.m.

SECOND SOUTHERN MUNICIPAL AND INDUSTRIAL WASTE CONFERENCE SCHEDULED

The Second Southern Municipal and Industrial Waste Conference, jointly sponsored by Duke University, University of North Carolina, and North Carolina State College, will be held at University of North Carolina, Chapel Hill, N. C., March 19–20, 1953. The theme of the Conference will be "Clean Streams in Our Southern Economy." The Conference program of speakers will be available by January 15.

Requests for copies of the program should be directed to Prof. D. A. Okun, School of Public Health, University of North Carolina, Chapel Hill, N. C.

ALGAE SYMBIOSIS IN OXIDATION PONDS

II. Growth Characteristics of *Chlorella pyrenoidosa* Cultured in Sewage

By William J. Oswald, H. B. Gotaas, Harvey F. Ludwig, and Victoria Lynch

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Oxidation ponds are widely used in the west and southwest United States as a simple and economical means of secondary sewage treatment. In the warmer climates, characteristic of this region, sewage in ponds decomposes rapidly, liberating principally ammonia and carbon dioxide. These compounds, together with adequate light, are the principal factors involved in the development of the green algae generally found in oxidation ponds. Among such green algae is *Chlorella pyrenoidosa*, a species frequently found near the pond outlet. *C. pyrenoidosa* is a well-known alga, widely used for laboratory experiments in photosynthesis and plant nutrition.

This paper is one of a series concerned with algae symbiosis in oxidation ponds. The first paper of the series (1) outlined the growth characteristics of a polysaprobic protozoan-like green alga, *Euglena gracilis*, when cultured in sewage. It introduced a number of relationships among the many variables influencing the complex biology of oxidation ponds. The application of these relationships to other algal species was unknown, and for this reason it was decided to repeat a major part of these experiments, utilizing a radically different alga. This paper deals with the growth characteristics of *C. pyrenoidosa* when cultured in sewage, and with the effects of the organism upon the sewage.

In the case of *E. gracilis*, properties of the cells (such as form, shape, size, density, color, rate of growth and photosynthesis, rate of respiration, vitality, and content of protein, carbohydrate, fat, ash, and various mineral ions) depend upon the environment to which the cells are exposed.

Cells exposed to favorable conditions (abundant nutrients and adequate light) are small, dark green in color, highly motile, rapidly growing and reproducing, contain a minimum of lipid, and photosynthesize much more oxygen than they respire. Cells of this type were designated as "young" cells. "Old" cells were described as those growing in an unfavorable environment; they are mostly in the palmellar state, are large and fat, yellowish in color, reproduce slowly, and may produce less oxygen than they require for respiration.

The studies with *Chlorella* were conducted in the same culture tubes as used for studying *Euglena*. These are 57-mm. pyrex tubes having a liquid volume of 1,200 ml., equipped with an internal cooling tube and peripheral 30-w. daylight fluorescent lights. Appurtenances permit feeding and withdrawal of liquid on a continuous basis and provide for bubbling air through the culture to maintain homogeneity. The assembly is designed to facilitate aseptic techniques in handling of the liquids.

During the series of tests herein reported the following factors were maintained at the following constant values: light, 1,200 fc.; temperature, 25° C.; air bubbling rate, 500 ml. per minute; B.O.D. of influent (5-day, 25° C., Warburg), 110 p.p.m. The single independent variable was the rate of application of sewage and equivalent withdrawal of the algal cell suspension. Since the total culture volume was held constant, the period that sewage was retained in the system was determined by the daily volume of sewage applied. This period has been designated as the retention period, R, defined as $R = V/v$, in which V is the culture volume in ml., v is the volume of feed or withdrawal in ml. per day, and R is expressed in days.

In performing any single test the retention period was held constant over the entire testing period, usually from 20 to 30 days. At the start of the test the 1,200-ml. tube was filled with sewage that had been inoculated with a pure culture of *C. pyrenoidosa* previously developed in sterile sewage in a separate culture flask. The content of the tube was then inoculated with a 10-ml. suspension containing approximately equal amounts of inoculum of 22 strains of sewage bacteria.* *Chlorella* populations in the growth units at the start were then about 0.1×10^6 cells per ml. and bacterial populations were about 1×10^6 colonies per ml. Daily tests showed that with $R > 3$, the algae entered a logarithmic phase of multiplication and increased to an equilibrium population of approximately 35×10^6 cells per ml. With $R < 3$, smaller equilibrium populations resulted. Under the regimen of continuous feeding and withdrawal, the equilibrium population for any condition may be maintained indefinitely. When daily control tests indicated that such equilibrium had been attained, the entire culture was sacrificed in order to have sufficient material for the numerous tests to be performed.

The retention periods investigated for *C. pyrenoidosa* varied from 0.5 to 8 days, and correspondingly the environment to which the algae were exposed varied progressively from very favorable (abundant nutrients) to very unfavorable (a shortage of one or more nutrients). Because the B.O.D. of the sewage was held constant at 110 p.p.m.† throughout the series, the B.O.D. loading is inversely proportional to the retention period. For example, at a retention period of 0.5 day, the B.O.D. loading is 220 mg. per liter per day; whereas at a retention period of 8 days the B.O.D. loading is about 14 mg. per liter per day.

Characteristics of *Chlorella* Cells

The several criteria previously developed (1), for evaluating the characteristic properties of *Euglena* cells in equilibrium cultures, were found to be applicable to *Chlorella* cells with certain exceptions.

1. Cell count, C. The number or population of cells per ml. of culture at equilibrium. A hyperbolic curve results when the cell counts are plotted as ordinates against elapsed time as abscissas, following the initial filling of the tube. Equilibrium is attained when the cell count, after increasing from its initial seed value, levels off at or near its maximum value. Equilibrium is usually reached, in the case of *Chlorella*, within a period of less than 10 days. A longer time is required to reach equilibrium when the retention period is shorter.

* These bacteria were originally isolated from sewage from three different cities—San Francisco, Richmond, and Concord, Calif. They are maintained in the laboratory by transfer to fresh sewage agar at two-week intervals. They include the following tentative and incomplete identifications: Nine strains of *Pseudomonas* sp., five strains of *Micrococcus* sp., and one strain each of *Bacillus subtilis*, *Alcaligenes faecalis*, *Escherichia coli*, *Flavobacterium* sp., *Streptococcus* sp., *Aerobacter* sp., *Proteus* sp., and *Neiserria* sp.

† The technique of preparing and maintaining a constant natural sewage is described elsewhere (2).

2. Cell shape. *C. pyrenoidosa* cells do not vary in shape but remain approximately spherical, whereas the *Euglena* cells alter from elongate to spherical. However, size changes and gross morphological variations do occur, as noted later.

3. Cell volume, V_m. The real volume, in cu. mm. of a million cells as determined by direct microscopic measurement. This measurement was undertaken for *E. gracilis* because cell shape had a decisive effect upon packing characteristics and altered the centrifuged volume. In the case of *Chlorella*, the measured volume and packed volume were found to be closely parallel, presumably due to the spherical nature of the cells. For this reason, real cell volume is not reported for *Chlorella*.

4. Packed volume, V_c. The centrifuged volume, in ml., of the cells contained in 1 l. of culture, after centrifuging at 500 *g*. The result is a function of the cell count and the cell volume.

5. Cell weight. The dry weight of cells in μg. (10^{-6}g.) per million cells.

6. Cell density. The dry weight of the cells, in mg. per cu. mm. of real volume.

7. Cell index, *I*. The packed volume, in cu. mm., of a million cells.

8. Cell color. This varies from dark green through yellow-green to yellow and brown, depending upon cell types and availability of nutrients. The intensity of green color depends primarily upon the chlorophyll content of the cells.

9. Chlorophyll content, Ch. The amount of chlorophyll, in mg. per mg. of dry cell material, or in μg. per million cells. Chlorophyll is measured spectrophotometrically in methanol solution by the methods of Mackinney (3) and calculated on the basis of the methods of Comar and Zscheile (4). Values reported are the sum of chlorophyll A and chlorophyll B. This measurement, not previously undertaken for *Euglena*, is now in routine use so that cell color changes may be systematically evaluated.

10. Cell types. Various cell types or forms of *Chlorella* cells are found, depending primarily upon cell "age." These forms, when plotted with ordinates superimposed, develop what may be termed a "morphological phase diagram." A similar diagram was developed for *Euglena* (1). The morphological phases for *Chlorella* are arbitrarily described as follows:

1. Unicell—Typical non-divided cell.
2. Giant cell—A "young" cell undivided.
3. Tetra cell—A giant cell showing four daughter cells either (a) within the old cell wall, or (b) newly separated from the old cell wall.
4. Diplo cell—A cell smaller than the giant cell and showing two daughter cells, either (a) within the old cell wall, or (b) newly separated from the old cell wall.
5. Degenerate cell—An old cell showing little chlorophyll content, large vacuoles, and many dark inclusion bodies.
6. Clumping cells—Cells showing a tendency to form palmellae.

11. Cell concentration, *D*. The oven-dry weight of the washed algal cells, expressed in mg. per liter of culture.

12. Yield, *Y*. The oven-dry weight of washed algal cells obtained daily, expressed in mg. per liter per day.

Growth Curves

Two growth curves for *C. pyrenoidosa* are shown in Figure 1. Diagram A shows the number of cells and the size of the cells in a batch culture as a function of time. Diagram B shows a cross-plot of the equilibrium populations and cell sizes in the continuous cultures as a function of the retention period.

Both curves show that the cells, initially young and large, become smallest near the time of maximum population. With increasing age the cells, on

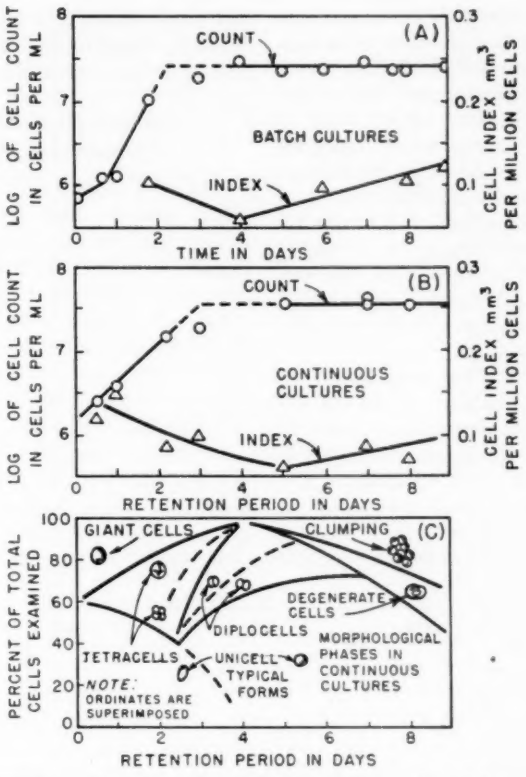

FIGURE 1.—Growth data for *C. pyrenoidosa* cultured in sewage.

the average, become larger and continue to enlarge throughout their aging period. Both curves also show a 2-day or 3-day period near the apex where cell division continues at the expense of cell size.

The similarity of the two curves is evidence that the retention period of continuous cultures represents the average age of the cells. Whether in batch or continuous culture, the individual algal cell may attain an age beyond which it can not divide, although it may continue to photosynthesize cell material and increase in size. This may come about through loss of ability to synthesize protein or through failure to obtain nitrogen in competition with younger cells. Diagram C of Figure 1 illustrates these morphological changes, which may be observed with the microscope.

Chlorophyll Content of the Cells

Figure 2A shows that chlorophyll content of the individual cell falls off rapidly as retention period increases. This indicates that the chlorophyll is broken down or inactivated as the cells become older, or else the older cells upon division contributed less chlorophyll to their daughter cells. Evidence sustaining the former possibility is indicated by the authors' recent unpublished work on the effect of light on algae growing in a sewage medium. With nutritional conditions remaining constant, the amount of chlorophyll present in individual cells is found to decrease as the amount of light avail-

able increased, whereas the rate of synthesis first increases and then decreases. Evidently chlorophyll is broken down in more highly illuminated, and older, cultures to a greater extent than in younger, less illuminated cultures. However, in even the oldest continuous cultures, as shown in Diagram C of Figure 1, a percentage of the cells remain young and retain the capacity to multiply. The burden of new cell synthesis may fall upon a diminishing percentage of cells as the average culture age increases.

The effect of the nutrition factor on chlorophyll production is shown by Figure 2B, which shows the chlorophyll content of the cell, in percentage of its total dry weight, as a function of the amount of applied food material. In the range where nutrition is limiting (that is, less than about 50 mg. per liter per day), where $R > 2.2$ days, the percentage of chlorophyll decreases as nutrition becomes more limited.

Chlorophyll Content and Synthesizing Ability

The relationship between cell chlorophyll content and cell synthesizing ability may be expressed as the ratio, mg. of cell material synthesized per day per mg. of chlorophyll present. In the range of limited nutrition (that is, where the B.O.D. loading is less than 50 mg. per liter per day), this ratio remains approximately constant at a value of 25.

At nutrient loadings greater than 50 mg. per liter per day, the ratio rapidly increases. This may be due to the greater light penetration attained at short retention periods, as a result of

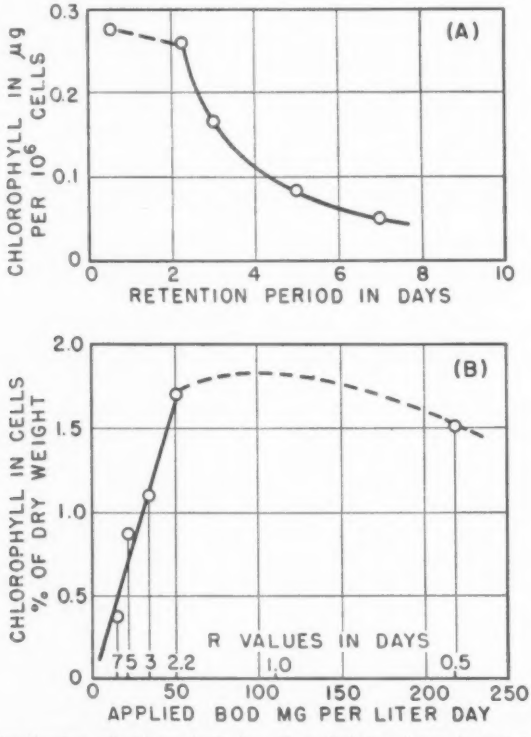

FIGURE 2.—Production of chlorophyll A + B at lighting intensity of 1,200 foot-candles.

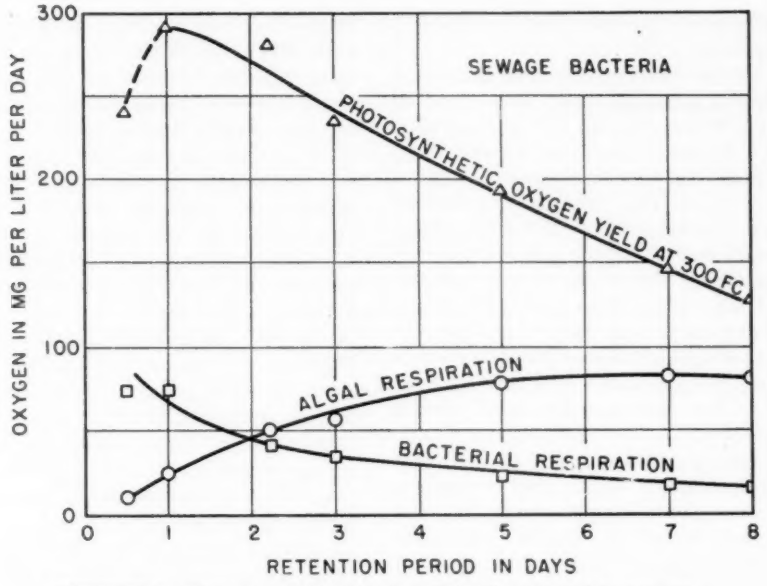

FIGURE 3.—Oxygen relationships for *Chlorella* cultured in sewage.

the marked decrease in density and turbidity of the culture.

Oxygen Production

In accordance with the simplified photosynthetic equation—

$$2\ CO_2 + 2\ H_2O \xrightarrow{\text{Light}} 2\ (CH_2O) + O_2$$

—the production of cell material is accompanied by a stoichiometric production of oxygen. The generally accepted pattern of this reaction is that oxygen is derived from the photochemical decomposition of the water molecule, rather than from a splitting of the CO_2 molecule. The CO_2 molecule serves as a hydrogen acceptor within the algal cell, resulting in production of a substance of the general formula CH_2O, which may be termed "primary cell material." The oxygen is liberated outside the cell and may then serve as the ultimate hydrogen acceptor for bacterial respiration in the aerobic decomposition of sewage. Thus, water serves as a hydrogen donor for the reduction of CO_2 in algal photosynthesis, and the liberation of oxygen is incidental to the process.

The oxygen liberated by *Chlorella* under varying B.O.D. loadings, under the experimental conditions, is shown in Figure 3. The curve of oxygen production reaches a maximum at a retention period between one and two days, and is similar in pattern to the curve showing cell yield (Figure 5). These oxygen production values were calculated on the basis of Warburg respirometer tests of *Chlorella* cells under illumination of approximately 300 foot-candles, as previously outlined (1). From these data the gross oxygen yield is computed, allowing for respiration both of the algae and bacteria in the system. This large excess of oxygen is in agreement with earlier findings for *E. gracilis*, which, under continuous lighting, was found to liberate oxygen in excess of the respiratory requirement of all organisms in the system up to a retention period of 16 days. However, due to the higher rate of growth, and perhaps due to its smaller size, *Chlorella* produces an excess of

oxygen greater than that produced by *Euglena*.

On the basis of chemical analysis of the cell material, using the method described by Myers (5), the ratio of CO_2/O_2 for *Chlorella* grown under continuous lighting in sewage is found to be −0.75. This value is in agreement with that reported by Myers for similar conditions. Utilizing this ratio and the previously noted chlorophyll determinations, calculations show that 66 mg. of oxygen per day may be produced by that weight of *Chlorella* which contains 1 mg. of chlorophyll at a light intensity of 1,200 foot-candles. This finding agrees with initial rates obtained in the Warburg respirometer at 300 foot-candles, and indicates that *Chlorella* is an excellent oxygen producer when grown in sewage under continuous lighting, particularly when an abundance of nutrients is supplied. It may also indicate that little added yield is obtained by increasing light intensity from 300 fc. to 1,200 fc.

Symbiotic Sewage Treatment

The liberation of large amounts of oxygen by *Chlorella* over the entire range of B.O.D. loadings studied, suggests that a high degree of sewage treatment (that is, bacteriological stabilization) may be induced by this liberated oxygen. Figure 4 compares the B.O.D. of the influent sewage with that of the culture, and of the algae-free culture supernatant. Despite the availability of oxygen in the culture, the B.O.D. of the clear supernatant is high compared to that obtained for *Euglena* supernatants. The B.O.D. of the whole effluent is similarly higher than for *Euglena*. It is much higher than that of the influent sewage for all but the shortest retention periods.

In support of these findings, bacteriological examination of the mixed liquor from the cultures showed a low bacterial population compared to bacterial populations attained in similar systems in the absence of algae and in systems containing *E. gracilis*, as follows:

Bacteria Recovered at Equilibrium Conditions

System	Colonies per ml.
Sewage plus bacteria	1×10^8
Sewage plus bacteria plus *Euglena*	5×10^7
Sewage plus bacteria plus *Chlorella*	1×10^6

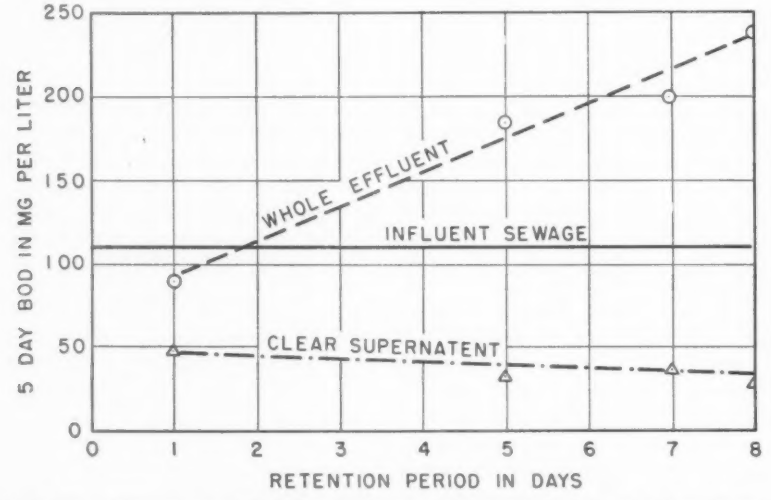

FIGURE 4.—Comparison of B.O.D. of influent sewage with B.O.D. of *Chlorella* culture and of culture supernatant.

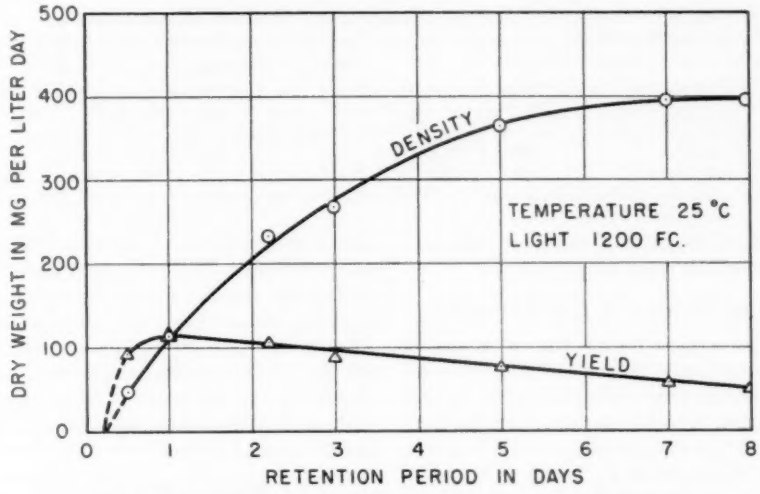

FIGURE 5.—Yield and density of *Chlorella* cultured in sewage.

Similar findings have previously been reported (6)(7). This evidence indicates that some factor inhibits bacterial action upon the sewage substrate while the *Chlorella* cells are present. The fact that the supernatant exerts a relatively high B.O.D. suggests that bacterial growth is less inhibited following the physical removal of the *Chlorella* cells. As previously noted, comparable supernatants from *Euglena* cultures had lower B.O.D. values, ranging from 10 to 20 mg. per liter.

In another series of tests, *Chlorella* was found to grow more vigorously and give higher yields of cell material in sterile sewage than it did when bacteria were present.

Yield of Algal Cell Material

Figure 5 shows the manner in which the yield of algal cell material increases with increased B.O.D. loading (reduced retention period). These data correspond closely to the data presented for *Chlorella* by Cook (8), differing only in the lower magnitude of the yield. In Cook's studies an extra supply of CO_2 was made available to the algae by fortifying the CO_2 content of the bubbling air to 5 per cent.

Calculations based upon algal cell analyses and sewage analyses indicate that the principal factor limiting increased yield at long retention periods, or low B.O.D. loadings, is a lack of carbon. The amounts of various nutrient elements made available when the B.O.D. loading is 15 mg. per liter per day are compared with the amounts required in the following:

	Nutrient (mg./l./day)					
	C	N	P	K	Ca	Mg
Available in sewage	13.2	3.00	1.00	1.90	3.00	1.10
Required for *C. pyrenoidosa*	24.0[1]	1.42	0.62	0.63	0.90	0.14

[1] 10.8 mg. supplied from bubbling air.

E. gracilis gave yields comparable to those of *Chlorella*, in spite of its slower growth rate.

Figure 5 shows that as the retention period is increased the density of the culture, expressed in mg. of cell material per liter of culture, increases continuously. This increase in density results in a reduction of the light entering the culture. Also, it results in a high B.O.D. load upon the system, due

TABLE I.—Comparative Analyses of *Euglena* and *Chlorella* Cultured in Sewage

Algae	Dry Weight (mg./l.)	Per Cent of Dry Weight							C/N
		C	H	N	P	K	Ca	Mg	
E. gracilis	368	49.	6.4	4.0	1.9	0.38	1.5	0.30	11
C. pyrenoidosa	390	49.	7.0	2.9	1.3	1.3	1.8	0.29	17

to the increasing respiratory requirements of the algal cells.

Composition of Cell Material

The comparative analyses of *E. gracilis* and *C. pyrenoidosa* (Table I) indicate that sewage-cultured *Chlorella* and *Euglena* are of similar composition. They differ mainly in carbon and nitrogen content; that is, in the C/N ratio. The analyses of Table I are for algae grown at a retention period of 8 days. This retention period is slightly above optimum for *Euglena*, but is greatly above optimum for *Chlorella*. The result is a higher C/N ratio for *Chlorella*, indicating storage of carbohydrate in the older cells. Since the culture density, *D*, continuously increases, whereas the population remains constant, the density of the individual cells increases with age, presumably because of storage of carbohydrates.

Carbon Balance

When grown experimentally in an inorganic medium, *Chlorella* is often supplied with air containing 5 per cent

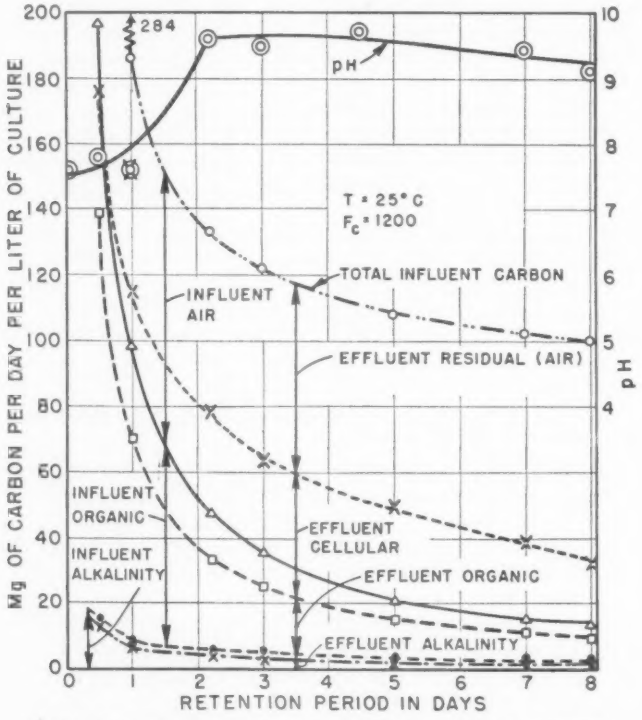

FIGURE 6.—Carbon balance for *Chlorella* cultured in sewage.

CO_2. This results in yields high above those obtainable with sewage and plain air. Probably higher yields of *Chlorella* in sewage could occur if more carbon were available from bacterial decomposition of the organic matter; but, as previously noted, bacterial examinations and B.O.D. determinations on the supernatant indicate that *Chlorella* inhibits bacterial decomposition of the sewage, thereby imposing a self-limiting factor upon its own growth. In the tests reported, only two other sources of carbon were available to *Chlorella*—the carbon contained in the alkalinity of the sewage and in the air employed for bubbling. The utilization of either of these carbon sources does not contribute to sewage treatment. Figure 6 shows the sources of carbon and its fate during the tests, as a function of retention period. The greatest source of carbon is from bubbling air. Reduction in alkalinity accounts for only a small fraction of the total carbon utilized. It is probable that *Chlorella* utilizes carbon sources (sugars) other than CO_2. The direct use of carbon sources independent of bacterial activity may partially account for the fair degree of sewage treatment obtained even though bacterial growth is inhibited.

Figure 6 includes a curve showing the pH of the culture at a varying retention period. With increasing retention period, up to $R = 2.2$, the pH of the culture increases, to a maximum of 9.6. Evidently the amount of carbon dioxide abstracted from the sewage alkalinity increases with retention period, with a corresponding increasing release of hydroxyl ions, up to $R = 2.2$ days. The reduction in alkalinity which also occurs is not associated with the abstraction of carbon, as explained previously (1).

Conclusions

Algae cells growing together with bacteria in laboratory culture units, with temperature and lighting constant, are greatly affected by the rate of application of nutrient sewage. At high rates of sewage application, corresponding to short retention periods, the cells are young, vigorously multiply, and photosynthesize abundant quantities of oxygen and cell material. As the retention period is increased, or the rate of loading decreased, the cells tend to remain in a vigorous multiplying state at the expense of cell size, but eventually at longer retention periods an increasing percentage of the cells cease to multiply and enter a phase of cell enlargement that leads ultimately to senescence and death. Senescent algae are yellow, low in chlorophyll, multiply infrequently, and may photosynthesize less oxygen than they consume in respiration. In the case of *Chlorella*, autolysis of older cells may serve as a meager source of nutrition for new cells, but their ultimate death leads to putrefactive decomposition and to effluent B.O.D. magnitudes far exceeding those of the influent sewage.

A continuous culture at some particular retention period resembles in many ways a batch culture having an age equal to that retention period. However, in batch cultures the organisms are in a changing nutritional environment, whereas in continuous cultures at equilibrium the environment is constant. For this reason the continuous cultures furnish experimental material for study of algal physiology in quantities that can be made available in no other way. By relating such laboratory findings to the natural phenomena in lakes, reservoirs, and ponds, where the sources of nutrients vary with the seasons, the reasons for sudden occurrence and death of algae may become apparent. For example, if nutrient materials enter the water body at some particular time, but no subsequent sources of nutrient are made available, bloom may occur and then be followed by senescence, death, and putrefaction.

Both *Chlorella* and *Euglena* have

been found to photosynthesize rapidly in a rich nutritional environment. Both tend to overextend their populations at the expense of parent cell material, and both pass through a microscopically observable series of morphological phases that remain remarkably constant when nutritional conditions are constant. Both algae enter a senescent phase that is marked by reduced photosynthetic capacity, yellow color, reduced chlorophyll content, and increased tendency toward cell enlargement with accompanying higher respiration rates. In both cases, if the cells are removed from the mixed liquor after growth, the supernatant has a low B.O.D. that appears to be essentially independent of retention period.

These similarities are offset by the following differences: *Chlorella* grows more rapidly than *Euglena*, entering the various phases at lower retention periods. *Chlorella* tends to autotrophic nutrition, and may decidedly inhibit the saprophytic bacteria necessary to the first-stage decomposition of sewage. By inhibiting such bacterial action, *Chlorella* may limit the carbon and nitrogen made available for its continued growth. Also, there is some evidence indicating that certain bacteria may inhibit the *Chlorella* itself. *Euglena* on the other hand, being a facultative saprophyte, appeared to grow better in the presence of sewage bacteria than in sterile sewage. There is no evidence of specific bacterial inhibition by *Euglena gracilis* (7).

In spite of its slower rate of growth *Euglena* compares favorably with *Chlorella* in the yield of cell material when grown in sewage. Cell-free supernatants from *Euglena* cultures are lower in B.O.D. than are *Chlorella* supernatants, and the whole effluents from *Chlorella* cultures show a high B.O.D. as compared to *Euglena* whole effluents.

Summary

Chlorella pyrenoidosa has been grown in continuous culture on preserved sewage in the presence of sewage bacteria in continuous light and at constant temperature. The morphology and physiology of this alga are greatly affected by the rate of sewage application. Symbiotic activity is reduced because of bacterial inhibition by *Chlorella*. The sewage treatment afforded by *Chlorella* and by the bacteria not inhibited by its presence is satisfactory but poor when compared with treatment obtained with *Euglena gracilis*. The results of the present experiments with *Chlorella pyrenoidosa* are compared to those previously reported for *Euglena gracilis* and are found to be generally comparable.

Acknowledgments

Appreciation is extended to the personnel of the Sanitary Engineering Research Project of the University of California, particularly to Professor P. H. McGauhey, Jerome Thomas, and Archibald Greenburg. Appreciation is also extended to Professor W. F. Langelier of the Department of Engineering and Professor Daniel Mazia of the Department of Zoology of the University of California. Their cooperation has greatly facilitated this work.

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THIRD QUARTER CONTRACTS TOTAL $43,000,000

Contracts for the construction of 161 sewage treatment plant projects, costing $43,000,000 were awarded by municipalities in 39 states during the third quarter of 1952, according to the U. S. Public Health Service. Of the 161 projects, 103 are for new plants and 58 are for replacements, additions, or enlargements. A total of 3,408,200 people will be served by the projected facilities.

The report is based on data obtained from state water pollution control agencies, the F. W. Dodge Corporation, and other construction news sources.

Thirty-nine states are represented on the list of projects reported for the third quarter. Of the 103 new plant projects, 13 are in California; 11 in Texas; 8 in Ohio; 7 in Florida; 6 each in Oregon and Pennsylvania; 5 in Georgia; 4 each in New York, Oklahoma, and Arkansas; and 3 each in Michigan, Minnesota, and Wisconsin. The remaining 26 new plants are scattered through 20 other states. Of the 58 additions, enlargements, or replacements, 11 are in California; 5 each in Ohio and Texas; 4 in Wisconsin; and 3 each in Illinois, Michigan, and Pennsylvania. The remaining 24 improvement projects are scattered through 16 other states.

DESIGN FEATURES OF THE CLEVELAND SOUTHERLY SLUDGE HEATER INSTALLATION *

By Frank S. Palocsay

Principal Engineer, Havens and Emerson, Consulting Engineers, Cleveland, Ohio

Before describing the design features of the Cleveland Southerly sludge heater installation, a brief review of factors entering into the design is in order.

Easterly plant sludge, amounting in 1951 to an average of 527,300 g.p.d. of combined primary and excess activated sludge concentrated to an average solids content of 3.25 per cent, is pumped approximately 13 mi. to the Southerly site, where it is merged with an average of 83,750 g.p.d. of sludge from a Southerly abbreviated aeration plant. This combined sludge is now digested in one or more of 12 heated digestion tanks arranged in two batteries of six hexagonal tanks each. Each battery is built around a hexagonal control chamber, each wall of which is common to one tank. Individual digestion tanks have a liquid volume of 160,167 cu. ft. giving a total combined capacity of 1,925,000 cu. ft. Gas production in 1951 averaged 710,000 cu. ft. per day.

The Southerly plant, which has been in operation for almost 25 years, serves an area which has developed rapidly during recent years. Need for expansion to meet the growth led to studies which resulted in decision to change from Imhoff tank-trickling filter treatment of the sewage to the activated sludge process. Principal reasons for this change in the treatment process were the high cost of cleaning badly clogged inert trickling filters and, further, a desire for works at a hydraulic elevation which permits of complete treatment at higher stages of the Cuyahoga River. The general plan evolved for meeting these conditions provides for treating an average flow of 68 m.g.d. as appropriate to the year 1970.

Plant Units

When completed, the plant will be comprised of single-story primary settling tanks; aeration tanks; sludge settling tanks; separate heated sludge digestion tanks; and tanks for elutriation of sludge, supernatant, and filtrate; and inclusive of sludge conditioning, vacuum filtration, and incineration.

Heated sludge digestion capacity is being increased to 2,887,500 cu. ft. by the construction, now nearing completion, of an additional battery of six tanks identical to those of initial construction as to arrangement, size, and capacity.

In carrying out the planned program, the existing Imhoff tanks will be remodeled and converted to unheated secondary digesters, but with provision for gas collection by the installation of steel floating covers. The converted Imhoff tanks will provide 1,400,000 cu. ft. of secondary digestion capacity.

Upon completion of the program, digestion capacity will total 4,287,500 cu. ft., adequate for 1970 conditions, when Easterly sludge is expected to average 845,600 g.p.d. and Southerly sludge 366,900 g.p.d., or a total of 1,212,500 g.p.d. of sludge averaging 3.4 per cent solids.

* Presented at 1952 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

Available Heat

The original digestion tanks at the Southerly site are heated by means of 2,500-ft. spiral coils of 3-in. pipe, with an average surface area of 2,093 sq. ft., in each tank. Heat is provided by four gas and two dual-fuel (gas or oil) hot-water boilers in each of the two control chambers (Figure 1), each boiler having an output capacity of 1,536,000 B.t.u. per hr. or a total of 442,368,000 B.t.u. per day. In addition, heat available from the cooling water from two 420-h.p. gas engine-driven blowers amounts to approximately 4,000,000 B.t.u. per hr., equal to 96,000,000 B.t.u. per day.

To raise the temperature of Easterly and Southerly sludge under 1951 conditions from 50° F. (winter) to 90° F. (assumed optimum), 203,684,000 B.t.u. would be required per day; 77,000,000 B.t.u. are required to compensate for radiation losses. It is obvious that adequate heat was available, yet it had been practically impossible, for long periods of time, to keep the desired temperatures in the digesters. During 1951, monthly average digestion tank temperatures ranged from a low of 66° F. in December to a high of 77° in August, September, and October, whereas the desired temperature would range from 85° to 90°.

Heat Transfer Loss

Investigation disclosed that scaling and deposits on the coils had reduced their heat transfer value within one and one-half years after construction to 7.9 and in five and one-half years to 4.4 B.t.u. per hour per square foot per degree temperature differential. After cleaning the coils, the heat trans-

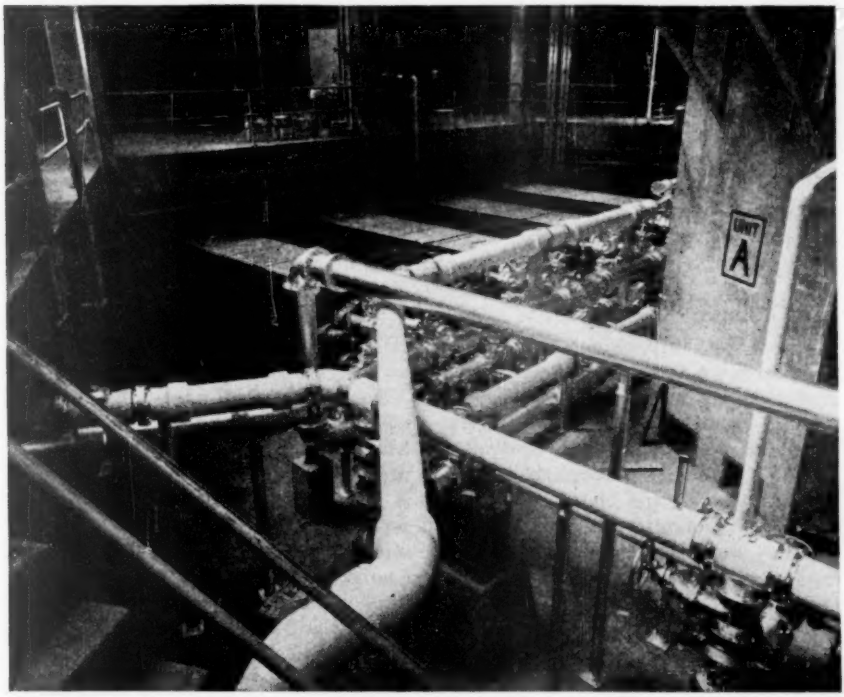

FIGURE 1.—East bank of heat exchangers in control chamber A. One of six existing hot-water boilers is visible on upper level at center.

fer coefficient was substantially increased, but it has again dropped.

Studies on sludge heating indicated that to provide adequate heat to the existing and new digesters would require increasing the heating coils in the 12 existing tanks by 35 per cent and installing 35 per cent more coil surface in the new tanks than there is in the existing; or to double the amount of heating coils in the proposed six new digestion tanks over that in the existing tanks. Additional water-heating boiler capacity and circulating pump capacity would also be required.

It also was found that, with the coil heaters, there was considerable variation in temperature at different points, varying anywhere from 4° to 18° in zones from top to bottom and with cold spots evident at various locations in the tanks. Then too, fluctuations in the amount of liquid sludge entering the digestion tanks (and, at times, its low initial temperature, especially when tank temperature was considerably below the optimum) had the effect of causing considerable variations in gas production—as, for example, from 16,000,000 to 37,000,000 cu. ft. in one month. Obviously, too, production was lowest in winter when the need for gas was greatest.

Heater Studies

Since best utilization of digestion tank capacity and optimum sludge digestion and gas production are closely related to the maintenance of relatively high temperatures controlled within a quite narrow range, studies were directed to determining the best means for accomplishing that objective. Not only was it important that, for the expanded plant, gas production be as high and as uniform as possible, but there also was the desirability of utilizing most efficiently all available waste heat from the existing and proposed gas and dual-fuel engine-driven blowers. These factors had much influence on the choice of the type of heating to be used.

Studies were made on various methods of digester heating, both internal and external, and on various types of external heaters. It was concluded that, to accomplish the desired objective, sludge should be heated to optimum temperature before discharge into the digestion tanks and in such manner as to utilize all engine waste heat. It was determined that this could best be accomplished by the use of external heaters of the heat exchanger type.

The 12 existing hot-water boilers were found to be in good condition and could be expected efficiently to supply hot water for use in heat exchangers. It was decided to continue their use in connection with heat exchangers, rather than to install self-fired conventional-type external sludge heaters. To this end, 10 external heat exchangers are now being installed at the Southerly plant.

Amount of Heat Required

It is pointed out that, for expected 1970 conditions, the heat required to raise the estimated 1,212,500 g.p.d. of Easterly plus Southerly sludge from 50° to 90° F. is 414,166,000 B.t.u. per day, with 115,500,000 B.t.u. additional in winter to compensate for radiation losses, or, at worst conditions, a total of 529,666,000 B.t.u. per day.

New Units

To preheat all incoming sludge, eight 2,500,000-B.t.u. per hr. output heat exchangers (Figure 1) are being installed in original control chamber A (Figure 1). Control chambers were fortunately built of ample size to permit of this installation. Sludge preheated to 90° F. will be discharged into any one or more of the 18 (12 original and 6 new) digestion tanks.

Radiation losses in the 12 original digestion tanks will be compensated for by the continued use of the heating coils, through which hot water will be

circulated as required to maintain the optimum temperature. Radiation losses in the 6 new digestion tanks will be made up by recirculating the digester contents through two external heat exchangers installed in the new control chamber C. These exchangers are similar to those used for preheating sludge, except that they have an output capacity of only 1,000,000 B.t.u. per hour. No coils or boilers are being provided for the new digestion tanks.

Initially, incoming cold sludge will be circulated through two of the eight preheaters, where sludge temperature will be raised as much as possible by utilizing all gas engine waste heat. The balance of the heat necessary to raise the sludge to the optimum temperature will be supplied in any or all of the remaining six heat exchangers in control chamber A by circulated heated water available from the existing 12 boilers, over and above that required for making up radiation losses.

Boiler-heated water will continue to be circulated through the pipe coils of the 12 original digesters, as well as through the two new smaller heat exchangers in the new control chamber C, for compensating for radiation losses. There will be no interconnection between gas engine heated and boiler heated water.

When the proposed new activated sludge plant is in actual operation and Southerly sludge is being digested, there will be available from the existing gas engines and from the proposed new engines a total of approximately 230,000,000 B.t.u. per day of waste heat. This, when added to boiler capacity of 442,368,000 B.t.u., giving a total of 672,368,000 B.t.u. per day, will be more than adequate to offset the total 529,666,000 B.t.u. per day required under maximum conditions to preheat all sludge from 50° to 90° F., and to compensate for all radiation losses in the 18 digestion tanks, and for 1970 conditions. When the new gas engines are in operation, two sludge preheating heat exchangers will be switched from boiler water to gas engine waste heat in order to utilize waste heat to best advantage and for maximum gas utilization. Four preheaters will then remain on boiler heated water.

Heat Exchanger Details

The eight external heat exchangers installed for preheating sludge are of a standard commercial design, 4 ft. 6 in. wide by 6 ft. 9 in. high by 17 ft. 8 in. over-all length, with 24 6-in. standard weight steel tubes having a total heat exchange surface area of 525 sq. ft. Sludge will be circulated through the tubes at a rate of 350 g.p.m. at 3.8 ft. per sec. velocity.

Concentric with and outside of the sludge tubes are 8-in. tubes to provide an annular space through which hot water will be circulated by means of centrifugal pumps. All pipe tubes are held firmly in position by special multiple-gasket joints so arranged that any leakage from the sludge tubes may be easily observed from the outside of the unit. Sealing of joints between the jacket water tubes, the end plates, and the return box fittings is so arranged that no leakage can occur between jacket water tubes and sludge tubes, thus assuring against contamination of hot water by any material circulated through the sludge tubes. Return bends are easily and independently removable so that the sludge tubes may be opened for inspection at both ends of each section without disturbing the jacket water tubes or jacket return boxes. All tubes may be removed for complete inspection or replacement.

The two recirculated sludge heaters are of the same general construction, but with tubes 10 ft. long and with 210 sq. ft. of surface area each. Heat transfer of the sludge heaters is based on 100 B.t.u. per hour per square foot per degree temperature differential, although it has been demonstrated that with circulated hot water the actual

heat transfer coefficient is nearer 150 B.t.u. This makes a substantial allowance for possible loss of heat transfer efficiency due to caking of the sludge coils between cleanings. It should be noted, also, that the hot-water temperature can be readily controlled to give extreme flexibility for any variation in sludge heating requirements.

Operation

The sludge heating operation is as follows:

Sludge is delivered to the concentration tanks, from which it will be pumped directly through the heat exchangers supplied by gas engine heat and then through as many of the other heaters as is necessary to bring the sludge to the optimum temperature (90° F.), after which the sludge will be discharged to any one or more of the 18 digestion tanks as desired by the operator. Sludge heaters are so piped (Figure 2) that sludge can be passed through them in parallel, in series, or in any desired combination. Indicating thermometers are provided at all water and sludge inlets and outlets and recording thermometers are provided on all sludge and hot-water inlet and outlet headers to give a permanent record of heater operation and efficiency.

It is recognized as important for good digestion that incoming sludge be seeded with digesting sludge. With external sludge preheaters this is usually accomplished by recirculating sludge at the same time that sludge is being preheated, thereby mixing some of the recirculated sludge with preheated sludge. At Southerly, seeding can be accomplished by turning over the contents of the digester receiving

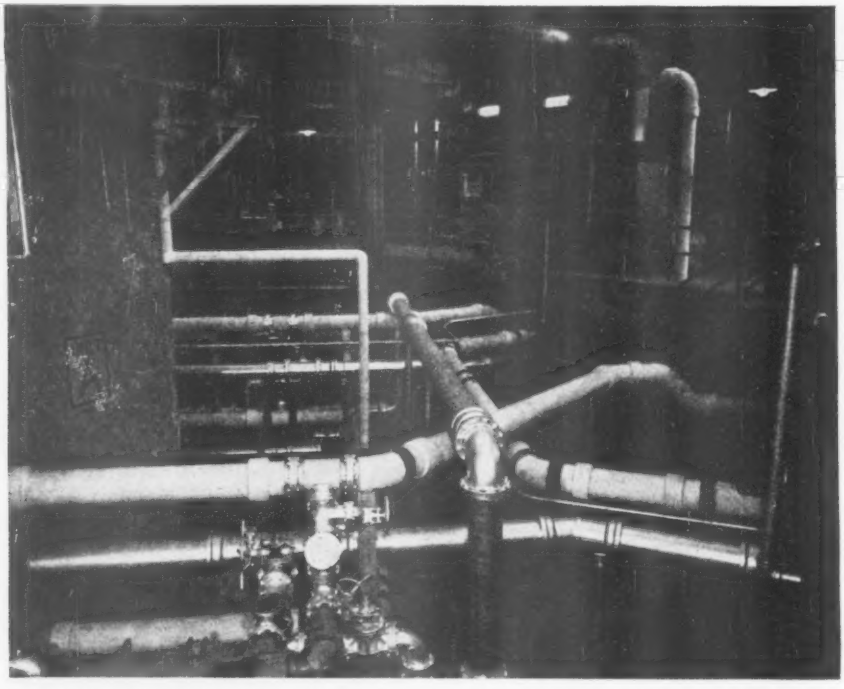

FIGURE 2.—Piping and heating water pumps in south end of control chamber A.

sludge at the same time that preheated sludge is being introduced, or immediately thereafter. Pumps and piping have been provided and arranged for this purpose.

No data can be given of the operation of the sludge heater installation as it has not as yet been put into service.

Acknowledgments

The Southerly project of improvement and expansion is under the Department of Public Utilities, City of Cleveland, of which Emil J. Crown is Director.

The planning of improvements at the sewage treatment plant is under the direction of G. Earl Flower, Commissioner of Sewage Disposal. Construction is under the supervision of Frank J. Schwemler, Commissioner of Utilities Engineering, City of Cleveland. Design was by Havens and Emerson, Consulting Engineers, Cleveland, Ohio.

ANOTHER COMMUNITY-WIDE INSTALLATION OF HOUSEHOLD FOOD WASTE DISPOSERS

Household food waste disposers are to replace the garbage man in Shorewood Hills, Wis., a suburb of Madison. According to L. J. Tooley, Village Manager and Engineer, the plan first was discussed after the village faced an increase in garbage collection costs because of the growing reluctance of farmers to feed garbage to their livestock. The disposal units will shred food wastes and flush them to the sewers, thereby eliminating the problems faced with truck collections.

The village decided to install the electric food waste disposers at village expense after studying reports from Jasper, Ind., which two years ago installed disposal units on a community-wide basis and found that general health and sanitary conditions had improved considerably (see THIS JOURNAL, **22**, 3, 288; **22**, 9, 1138; **23**, 3, 278; and **24**, 12, 1466: Mar. and Sept., 1950; Mar., 1951; and Dec., 1952).

The disposal units are to be purchased by the village, which will retain title and install them in all homes in the community. Payments will be made from village funds over a period of 10 years. Annual amortization cost over the 10-year period will be about equal to the current yearly collection expense. Installation of the units began in November, 1952, with an expectancy of completing the project in about eight months.

Industrial Wastes

TREATMENT OF FINISHING PROCESS WASTES AT THE TERNSTEDT INSTRUMENT PLANT *

By A. W. Sundwick and J. S. Delos

Respectively, Engineer-in-Charge, Process Engineering Dept.; and Chemist, Ternstedt Division, General Motors Corp., Plymouth, Mich.

The Ternstedt instrument plant in Livonia, Mich., started operations in the spring of 1951 with a contract to produce range finders for the Army Ordnance Department. The manufacturing operations included the application of an anodized and black-dyed surface to aluminum alloy castings and several chemical surface treatments for bronzes, brasses, and steels, besides the machining and assembly operations required to produce a finished instrument. The waste disposal problems discussed here are concerned only with the chemical solutions used for applying these surface finishes.

Due to the inadequacy of the city's sanitary sewage system, it was necessary that all of the process wastes be discharged into an open stream. This small stream, which has a total flow of approximately 10,000 g.p.h., is a tributary of the Rouge River, which flows through a residential area and through Rouge Park. Plant management recognized it as a responsibility to the community to make every effort to prevent any unnecessary pollution of the stream. To do this, it was necessary to set up methods and equipment which would remove harmful or undesirable elements from the waste process waters before discharging them from the plant.

In the absence of knowledge of any maximum allowable limits of concentrations of the elements under consideration, plant standards were set up for copper, chromium, zinc, iron, and manganese, based on the requirements of the U. S. Public Health Drinking Water Standards of 1946.

Sources of Pollution

The plant processes necessitate the use of 20 different chemical solutions. These are contained in 73 different process and rinse tanks. The greatest volume of untreated waste water is in the form of dilute solutions of sulfuric acid, chromic acid, sodium dichromate, nickel acetate, Nigrosine black (black dye), and caustic soda. These are the result of rinsing the processed part after removal from the processing solutions. To limit the volume of the total solution which has to be treated, so-called "drag-out" tanks have been installed. These tanks are placed next to each process tank and are used to rinse the major amount of the relatively concentrated process solution from the parts before they are rinsed clean in a "flowing rinse." Process and rinse tank sequences are shown in Figure 1. The drag-out tanks are still-water tanks, which are drained and treated according to schedule, whereas the flowing rinse tanks discharge continuously directly to the stream.

By experiment, later substantiated by actual practice, a frequency was established for dumping and treating the drag-out tanks such that the flowing

* Presented at 1952 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 19–21, 1952.

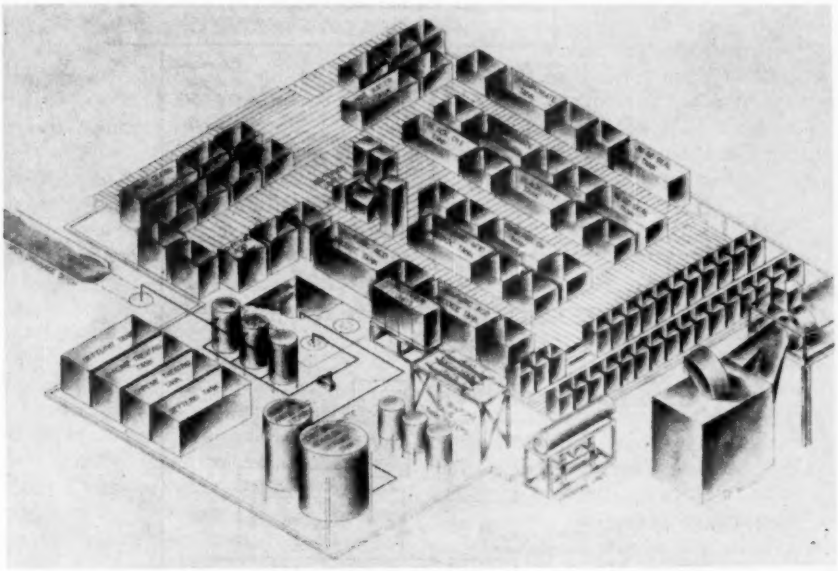

FIGURE 1.—Schematic layout of process area for chemical finishing.

rinse contamination was constantly maintained well below the allowable concentration limits. The method chosen to remove the elements was fundamentally to precipitate and filter. The equipment consists of settling tanks, pumps, and a bank of three commercially available porous stone filter units. The flow sheet (Figure 2) shows their position in the system. The sump, which is located in the immediate vicinity of the process tanks, is below the level of the floor. This arrangement provides a means for safely catching any accidental overflow and also allows a means for washing down the floor, as is occasionally necessary.

Treatment Procedures

The chemistry of the treatment operations might be described as follows:

For Removal of Sulfate

Any waste sulfuric acid anodize solutions are pumped to the acid holding tank, as are hydrochloric acid, nitric acid, and nickel acetate. Waste cleaners and other alkaline wastes are pumped to the alkali holding tank, and are used when necessary and available for neutralizing the acid wastes. Waste ammonia solutions are sent to the sump with the acid wastes, since adding them to the waste cleaners would cause evolution of ammonia fumes. The contaminated acid rinse waters, or specifically the drag-out tanks following the acid process tanks, are dumped directly to the sump. The pH is adjusted to approximately 7.5 to 8.5 with waste cleaners or with soda ash. This solution is then filtered to remove any iron hydroxide. The small quantity of sulfate in this water is well below the maximum allowable concentrations and, therefore, no attempt is made to precipitate it.

Acid wastes from the acid holding tank are neutralized in the sump with alkaline wastes and, if they contain sulfuric acid in sufficient quantity, lime is added in amounts determined by chemical analysis in order to form a precipitate. The resulting suspension of calcium sulfate is then pumped out of the sump to the filtering units, or to the

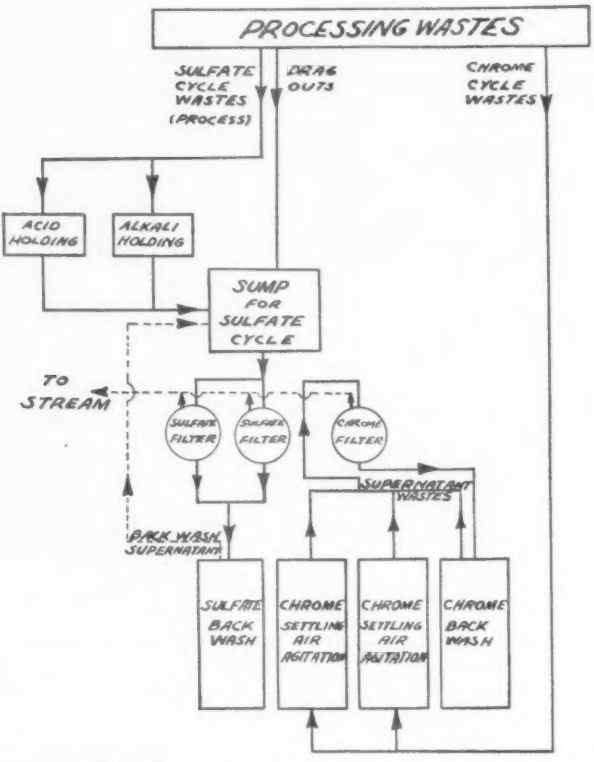

FIGURE 2.—Flow diagram for chemical finishing area wastes disposal.

settling tanks if the quantity of sulfate involved is exceptionally large. A filter aid of diatomaceous earth is added in each case to the filter unit. The filtrate after the removal of either the iron hydroxide or calcium sulfate is discharged to the stream and the precipitate is backwashed with the filter aid to a settling tank. Later, the supernatant liquid from this settling tank is drawn off and returned to the sump. The relatively dry precipitate is then shoveled out of the settling tank, placed in drums, and hauled away.

For Removal of Chrome

Any waste chrome solution is pumped to the chrome settling tanks. This includes the chromic acid anodize solution, the sodium dichromate sealing solutions, and also the contaminated rinse waters from these process tanks. In practice, the bulk of the volume requiring treatment is from the drag-out tanks. These rinse waters are pumped to the settling tanks, neutralized with soda ash or waste cleaners, and precipitated with barium chloride. Rigid chemical control is necessary to insure addition of correct amounts of barium chloride. Any excess of this compound would pass through the filter and be discharged into the stream. The whole solution is agitated and mixed by bubbling air through it. The precipitate is then allowed to settle and the relatively clear supernatant liquid is passed through the filter unit. The filtrate is discharged to the stream and the barium chromate plus the filter aid is backwashed to a collecting tank and allowed to settle. The supernatant liquid from

this settling is again filtered. The precipitate in both cases is shoveled into drums and disposed of in a fashion similar to that of the backwash solids from the sulfate cycle.

It will be noted that the load on the filter units has been considerably reduced by allowing time in the settling tanks for separation of the precipitated solids. Since the supernatant liquid is relatively free of solids, a finer filter medium can be used without risking overloading and clogging, than would otherwise be possible with the quantities and capacities available.

Each of the filter units contains about 96 sq. ft. of filter area and can pass approximately 25 g.p.m. at a maximum allowed pressure differential of 25 p.s.i. Considering the fact that 8,000-gal. storage volume is provided, it would be possible to process the largest volume of waste reasonably to be expected in about 6 hr. Except for the time necessary to rebuild process solutions, this could be accomplished without interrupting productive operations.

Process Economics

The records show that approximately 10 tons of barium chloride are being used to treat 1 m.g. of waste solution at a cost of 10¢ per pound for technical grade barium chloride. The manpower required is approximately equivalent to one full-time man, including the technical services of the chemist as well as the man who performs the actual labor involved. The total cost of the equipment, including the underground sump, catch basins, tanks, pumps, valves, fittings, filters, and mixers, is about $35,000. All of the equipment is such that, with reasonable care, repair or replacement of parts should be a minor item. The fact that it is necessary to treat the wastes has resulted in a greater effort to correct contaminated process solutions in order to escape the task of processing them through the waste disposal system. Success in repairing such process baths without appreciable loss of time to production, is believed to have resulted in an over-all saving. The possibility that impure barium chromate may have some salvage value is being investigated.

System Efficiency

In spite of the fact that waste disposal as a process is a novelty to the company, the procedure and system used is simple and straight-forward and agrees with common chemical engineering practice. After consideration of various disposal processes, the ideas of plant personnel were submitted to Hall Laboratories, Inc., for their opinion. This concern then set up the procedures and made recommendations as to what was felt would be satisfactory equipment.

As an example of the efficiency of the system, the following figures, representing the analysis of the stream water before and after plant operations were begun, are presented.

	Before Operation	During Operation
pH	7.4	7.3
Chloride (p.p.m.)	14	58
Sulfate (p.p.m.)	25	25
Suspended solids (p.p.m.)	239	22
Total solids (p.p.m.)	288	242
Chromium, hex. (p.p.m.)	0.1	0.00
Total iron (p.p.m.)	1.7	0 8
Manganese (p.p.m.)	0.1	0.1
Zinc (p.p.m.)	0.4	0.0
Copper (p.p.m.)	0	0.1

It will be noted that a substantial reduction in the amount of suspended solids has been accomplished, besides a general lowering of the metal ion concentration. From the results of these analyses it would seem that there has been an actual improvement in the quality of the stream by discharging the treated waste water into it.

APPLICATION OF BIOLOGICAL METHODS IN THE TREATMENT OF RADIOACTIVE WASTES *

By C. C. Ruchhoft and L. R. Setter

Sanitary Engineer Director and Senior Scientist, respectively, U.S.P.H.S., Environmental Health Center, Cincinnati, Ohio

The objective of this paper is to review some general aspects of radioactive waste disposal problems and point out the possibilities of the use of biological methods in the treatment of such wastes. It is impossible in the present paper to go into details as to the fundamental principles of radiation or all phases of radioactive waste problems. There have been many papers recently which discuss the elements of radioactivity. Briefly, radioactive substances are unstable and are continuously disintegrating through the emission of alpha or beta particles and sometimes electromagnetic (gamma) rays. These are all ionizing radiations and are, consequently, destructive to body tissues, depending upon intensity and duration.

The radioactive waste disposal problem has grown by leaps and bounds along with the rapid development in the use of radiation equipment, Atomic Energy Commission reactors, and radioisotopes for scientific uses. It is interesting to observe that in the Federation of Sewage and Industrial Wastes Associations' "Review of Literature for 1951" (13), there are references to 94 articles dealing with radioactive wastes in some manner.

There are liquid, solid, and gaseous radioactive wastes, but this paper is concerned primarily with the liquid wastes. The principal producers are the Atomic Energy Commission installations, particularly reactors and processes leading to the production of radioactive isotopes, although hospitals, research laboratories, and industrial users must be included as producers of radioactive waste.

Classification of Waste

The liquid wastes may be classified on the basis of the type of radioactivity emitted, the energy level, the rate of natural decay or half-life, and the biological toxicity or half-life. All of these factors are important in considering methods of waste treatment. The radioactive density of a waste may vary tremendously, from levels slightly above the natural background of water to very high values. Generally, only relatively low-level radioactive wastes, regardless of type, can be considered for biological treatment. The half-life of the isotope, which may vary from millions of years to seconds, also affects the treatment to be given the waste. Materials containing only short half-life isotopes of a few days or less can be stored to allow the activity to decay for about 10 half-lives and then discharged into a sewage system. The hazard from such disposal will be relatively low, provided the residual radioactive density of the liquid or sludge is not dangerous to personnel. Low-level waste containing long half-life isotopes, such as plutonium, may be successfully treated by industrial water and sewage treatment processes, including biological processes, to levels permissible in drinking water.

Methods of Treatment

The specific method of treatment selected for a waste will depend upon the

* Presented at 1952 Annual Meeting, Central States Sewage and Industrial Wastes Association; Madison, Wis.; June 25–27, 1952.

type, toxicity, and radioactive concentration of the waste and may include physical, chemical, biological, or a combination of these treatment processes. The common physical methods of disposal include storage, evaporation and storage of the solids, ground and sea burial of solids and liquids, and dilution. The evaporation and storage of concentrated waste is generally the method of choice for high-level wastes because the volume to be stored is reduced and the condensate is relatively free of radioactivity. It should be noted that the radioactivity is simply separated from the liquid and retained in a small residual volume, which must be stored. If the materials have a long half-life, the storage must be for a long time. Thus, plutonium waste would require storage for 250,000 years before the activity decayed through 10 half-lives.

Figure 1 shows a system of evaporation which has been developed by McCullough and associates (4). This is very effective and permits the discharge of the vapor condensate to the neighboring stream with practically no contamination therein. However, this method of disposal is very costly. The cost of disposal by evaporation in Atomic Energy Commission installations has been stated to be 8¢ to 12¢ per gallon. Compared to ordinary sewage treatment, 8¢ per gallon or $80,000 per m.g. is a tremendous cost.

Burial in the ground has been proposed for some kinds of radioactive waste. The problem of ground burial is receiving the attention of the Subcommittee on Waste Disposal and Decontamination, National Radiation Protection Committee, National Bureau of Standards. A Bureau of Standards memorandum on this method for guidance of those charged with responsibility for the safe disposal of radioactive isotopes is to be published soon. Disposal at sea is another common method being practiced by the Armed Services and the National Institutes of Health. The National Bureau of Standards Subcommittee is

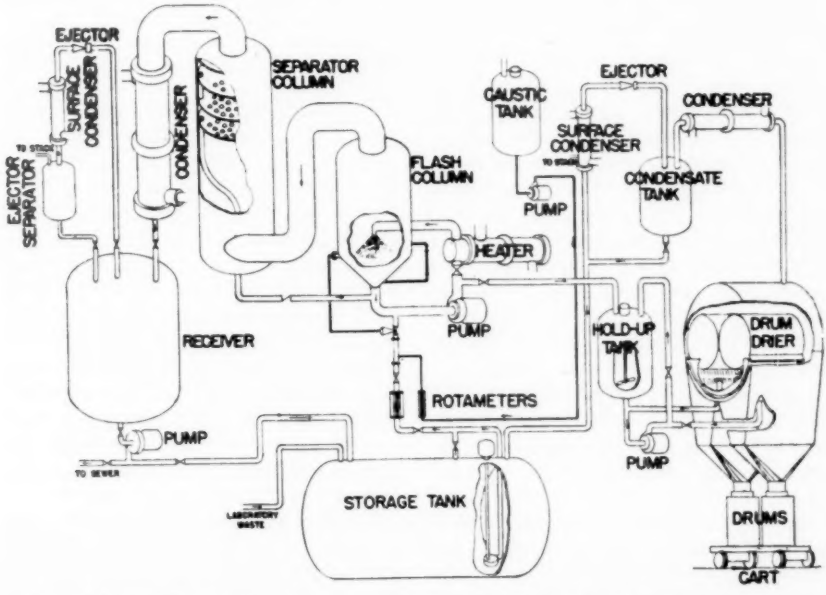

FIGURE 1.—Flow diagram for a system of evaporation of liquid radioactive wastes.

currently preparing a manual for guidance on sea disposal. The Atomic Energy Commission has also considered the return of waste and used isotopes to the Commission in case of hazardous materials in quantities which cannot be easily disposed of by isotope users.

The discharge of isotopes into sewers is of immediate interest to members of the Federation of Sewage and Industrial Wastes Associations. So far, the Waste Disposal Subcommittee, previously mentioned, has considered only the disposal of I^{131} and P^{32} as permissible. The levels and quantities which may be discharged into sewers under prescribed conditions from hospitals are given in Handbook No. 49 of the National Bureau of Standards (5).

The handbook recommends discharge of institutional wastes in a manner that will not permit a transient concentration higher than 100 microcuries per liter. One would have to drink a whole liter of such sewage to obtain a permissible tracer dose of P^{32} and I^{131}. It was presumed that the consumption of such a quantity of sewage would be a rare accident and, consequently, the ingestion of a tracer dose could be tolerated. This concentration would exist only in the sewage leaving the institution and would be greatly diluted in the trunk sewer and the interceptor before reaching the treatment plant or final discharge point into a stream. It would be interesting to estimate the ultimate equilibrium concentrations of these isotopes that may be expected if the daily isotopic wastes are diluted and mixed with the quantity of water used daily in the city. It is realized that the distribution of hospital facilities and sewage collection facilities would not be such that the waste could be expected to be uniformly diluted in the entire city flow. However, the theoretical values obtained in this calculation (see Table I) are instructive in showing the relative magnitude of the radioactivity to be expected from this source. It will be noted that the radioactivity from these isotopes diluted in this manner varies from 0.25 to 0.6×10^{-4} μc. per liter, and even if all the I^{131} and P^{32} waste in any of these cities was diluted into a system carrying only 2 per cent of the daily water supply, the expected radioactive concentration would still be less than the permissible level in drinking water for continuous use.

TABLE I.—Concentration of I^{131} and P^{32} to Be Expected in Sewage of Six Large American Cities[1]

City	Dilution Water Needed[2] (g.p.d.)	Water Consumption (m.g.d.)	Activity after Dilution[3] (μc./l.)
New York	413	925	0.4×10^{-4}
St. Louis	95	160	0.6×10^{-4}
Chicago	363	900	0.4×10^{-4}
Los Angeles	94	350	0.27×10^{-4}
New Orleans	25	60	0.4×10^{-4}
San Francisco	25	100	0.25×10^{-4}

[1] Based on the quantities of these isotopes shipped to the cities listed by the Atomic Energy Commission during the first six months of 1950 (11).

[2] Water needed to dilute activity to 100 μc. per liter assuming no decay.

[3] Activity from I^{131} and P^{32} after uniform dilution by volume of water used per day.

It may be remembered that 1 μc. is 2.23×10^6 atoms disintegrating per minute. Thus, 0.25×10^{-4} μc. is only 55 atoms disintegrating per minute. Consequently, quantities of radioactive elements which may be easily detected by radioactive assay are trace amounts, which could not be detected by ordinary chemical analysis. To understand the significance of the concentration that may be expected in interceptors, it may be interesting to compare these values with the standards that have been suggested by the Atomic Energy Commission for drinking water under various conditions.

Table II shows the permissible levels of alpha and beta activity in drinking waters, as proposed by several authorities. It will be noted that these values

TABLE II.—Proposed Levels of Radioactivity in Drinking Water (μc. per l.)

Time Water Is to Be Consumed	Max. Permissible Level[1]		Emergency Low-Risk Level[2]		Emergency Permissible Limit[3]	
	Alpha	Beta	Alpha	Beta	Alpha	Beta
10 days	—	—	0.2	3.5	5	90
30 days	—	—	0.07	1.1	1.7	30
Continuous use:						
Iodine^{131}	—	0.3	—	—	—	—
Phosphorus^{32}	—	0.2	—	—	—	—
Strontium^{89}	—	0.2	—	—	—	—
Strontium^{90}	—	8×10^{-4}	—	—	—	—
Radium^{226}	4×10^{-8}	—	—	—	—	—
Plutonium^{239}	1×10^{-3}	—	0.02[4]	—	—	—
Unknown sources	1×10^{-4}	1×10^{-4}	—	—	—	—
Fission product	—	—	—	0.004[4]	—	—

[1] Reference (16).
[2] Reference (17).
[3] Application of a safety factor of 25 to AEC permissible limits (18).
[4] Safe levels (19).

are much higher than the values to be expected after complete dilution in sewage of metropolitan areas in the United States (Table I).

The radioactivity for various natural springs is shown in Table III. For comparison, the permissible levels in drinking water for continuous and emergency use and the theoretical concentration from the discharge of I^{131} and P^{32} for St. Louis sewage are also included. It will be noted that the St. Louis sewage radioactivity concentration, which is representative of what may be expected in any metropolitan sewage, is much lower than the value for P^{32} in water for continuous use. The background levels for normal surface and ground waters of the United States are also included in Table III. A

TABLE III.—Radioactivity of Some Spring Waters Compared to Emergency Permissible and Background Levels and the Theoretical Value in St. Louis Sewage

Location	Source	Radioactivity (μc./l.)	Reference
Saratoga Springs, N. Y.	Hathorn No. 1	1.42×10^{-4}	(3)
Yellowstone Park, Wyo.	Monmouth Hot Springs	14.4×10^{-4}	(3)
Hot Springs, Ark.	Imperial Spring	90.3×10^{-4}	(3)
Manitou, Col.	Shashone Spring	33.8×10^{-4}	(3)
Ischia, Italy	Old Roman spring	$1525. \times 10^{-4}$	(3)
U. S. normal surface waters	15 samples	$.0036$ to $.0341 \times 10^{-4}$	(3)
U. S. normal ground waters	25 samples	$.0058$ to $.039 \times 10^{-4}$	(3)
St. Louis sewage	(Theoretical)	0.6×10^{-4}	1
Emergency drinking water	(Alpha, acceptable for 10 days)	$50{,}000 \times 10^{-4}$	2
Emergency drinking water	(Alpha, acceptable for 30 days)	$17{,}000 \times 10^{-4}$	2
Continuous use of drinking water	Unknown	1.0×10^{-4}	2
Continuous use of drinking water	Phosphorus^{32}	$2{,}000 \times 10^{-4}$	2

[1] See Table I.
[2] See Table II.

careful comparison of the data in Table I with the permissible radioactivity in drinking waters suggested by the Atomic Energy Commission indicates that there need be no fear of the contamination of surface waters from the I^{131} and P^{32} wastes presently being discharged into sewers by medical users.

Chemical Methods

Chemical methods for the treatment of radioactive waste include:

1. Deposition on metal or absorption on activated carbon, clays, or other adsorbants.
2. Ion exchange processes.
3. Coagulation and/or carrier precipitation, followed by filtration.

Many papers on the use of chemical procedures have been published. The use of coagulation-carrier precipitation in a waste-water treatment plant similar to that used in ordinary water purification practice has been applied at Los Alamos, N. Mex., (7) (10).

Biological Methods

The biological treatment which would be applicable to relatively low-level radioactive waste includes activated sludge, trickling filter treatment, and absorption by algae and other plankton forms. To date there have been no reported applications of the latter method, although algae and plankton serve as concentrators of activity in streams even when they are slightly polluted with radioactivity.

The application of biological methods to the treatment of radioactive waste was first studied at Los Alamos (6) (8) (9). It was found that activated sludge and trickling filter processes could be successfully used in the removal of plutonium in low concentrations from the waste waters. Studies at Los Alamos also indicated that biological processes were of special importance and were the only practical methods available for treating waste relatively high in organic acids which sequester the coagulants used in chemical treatment. It was also shown by this laboratory that an activated sludge capable of removal of radioactive materials could be produced from ordinary nutrients such as glucose and flour (12). On the basis of a continuation of experiments at Los Alamos, a plant for treating an unusual waste containing considerable quantities of citrate (sometimes as high as 20,000 p.p.m.) has been built and operated.

Preliminary bottle experiments have been conducted at the Cincinnati Environmental Health Center on the removal of P^{32} and I^{131} by activated sludge. A single experiment on the treatment of mixed fission products by activated sludge has also been completed.

General Experimental Procedure

Graduated cylinders of 1-l. capacity having a bottle-type neck were used as aerators by submerging a 1-in. ceramic diffuser ball at the end of a rubber tube to the bottom of a cylinder containing 1 l. of mixed liquor under aeration. Compressed air was admitted to each cylinder at a liberal rate, which neither caused settling of sludge nor troublesome foam.

A six-day "cold run" (that is, without radioactivity) preceded the phosphorus studies for the purpose of making adjustments in aerator solids and testing the technique of operation. The mixed liquor originally placed in the aerators consisted of 200 ml. of activated sludge and 800 ml. of feed. The activated sludge had been acclimated for several months on the type of food to be used.

Feeding Schedule

From Monday through Friday of each week, the aerators were fed twice daily at 8:30 to 9:00 AM and again at 4:00 to 4:30 PM. After sampling mixed liquor, the air diffuser was removed to allow the sludge to settle for 30 min. Between 700 and 800 ml. of the cloudy

supernatant were then decanted and immediately replenished to the original 1-l. volume with sewage or tap water containing the required amount of nutrients and minerals.

Tests

A 50- to 100-ml. sample of mixed liquor was withdrawn with a pipet for purposes of testing the suspended solids and sludge radioactivity. The sample of mixed liquor withdrawn for test purposes was usually sufficient to maintain a constant aerator solids content. The volume of sludge after settling for 30 min. was recorded and used to determine sludge volume index (S.V.I.) and control operation.

Samples of supernatant after 30 min. settling were tested periodically for pH, 5-day B.O.D., and suspended solids as indices of operation. Duplicate 10-ml. volumes of supernatant were evaporated in aluminum dishes at low heat and assayed for radioactivity by counting on the second shelf of a Geiger-Muller end-window counter. The efficiency of the counter was determined to be 6.53 per cent of the disintegrations based on a calibration of P^{32} standards counted in an internal proportional counter. Correction factors for geometry, self-absorption, backscatter, and extended source were applied to the internal proportional counter data.

The counting data of morning samples were determined within a matter of an hour or two, so no correction for decay was made. On the other hand, the afternoon samples were counted 24 hr. after sampling on week days and the Friday afternoon samples were counted on Monday afternoon, so appropriate decay factors were applied.

The radioactivity of the sludge solids was determined by centrifuging 50 ml. of mixed liquor, transferring the centrifuged cake to aluminum counting dishes with distilled water, evaporating slowly to dryness, and counting. The Geiger-Muller end-window counting rate was corrected for self-absorption and coincident losses.

Feed

Two of the four sludges in an experimental run were fed 700 to 800 ml. of domestic sewage twice daily, 5 days per week, for 2 weeks. The other two sludges were fed synthetic sewage consisting of a mixture of flour and sugar in 700 to 800 ml. of tap water twice daily, 5 days per week, for 2 to 4 weeks. The synthetic sewage feed was usually fortified with stable phosphorus (P^{31}) as trisodium phosphate, to maintain control of the process. All sludges received about 0.5 μc. of radioactive element at each feeding. Radioactive phosphorus (P^{32}) was added as a phosphate salt and radioactive iodine (I^{131}) was added as potassium iodide.

Uptake of P^{32} by Activated Sludge

In designing an experiment to determine the uptake of P^{32} by activated sludge, it was learned from previous studies (12) that phosphorus additions to common foods were essential to activated sludge process control. White flour contains from 0.09 to 0.10 per cent of total phosphorus and it might be assumed that this would provide ample available phosphorus for the metabolic requirements of the sludge. However, the experiments (12) indicated that about 3.0 p.p.m. or more of supplemental phosphorus, as phosphates, were required with the common food being used to produce sludges with satisfactory settling indices. In the later experiments the lack of sufficient available phosphorus to produce a sludge with a satisfactory settling index was considered the criterion for phosphorus deficiency. The stable phosphorus content of domestic sewage is fairly constant and has been reported (14) to average from about 1.7 to 4.0 p.p.m. as P. Usually, domestic sewage provides sufficient available phosphorus for process control. Since microorganisms do not differentiate between iso-

topes of the same chemical element in identical chemical form, the uptake of radioactive phosphorus will depend upon the abundance and availability of the total phosphorus. In view of this fact, the addition of 10 mg. of stable (non-radioactive) phosphorus per μc. of radioactive phosphorus waste had been recommended (1) as a method of waste disposal to sewers.

In these experiments the uptake of radioactive phosphorus was studied in four aerators. Of these aerators, A and B were fed flour and glucose, and were also given 1 and 3 p.p.m. of stable phosphorus, respectively. Aerators C and D were fed settled sewage. Aerator C received no additional supplemental stable phosphorus, but aerator D received 3 p.p.m. of stable phosphorus in addition to the sewage. The stable phosphorus (P^{31}) was added as a stock solution of trisodium phosphate. The aerators were fed every morning and afternoon immediately following the removal of 700 to 800 ml. of settled supernatant from the 1-l. aerators. The experiment was continued for two weeks with no feeding over the week end. The operating data on the activated sludges and the results on the removal of P^{32} are summarized in Table IV.

An inspection of the operating data indicates that:

1. The aerators were loaded with 33 to 35 lb. of B.O.D. per day per 1,000 cu. ft. of aerator capacity. However, the B.O.D. load per unit of aerator solids was least in the sewage-fed sludges, C and D, and most in sludge A.
2. The supernatant suspended solids are relatively high for normal plant operation on continuous feeding. However, laboratory batch feeding twice daily with excess air usually produces more turbid effluents. Somewhat better removal of P^{32} associated with these solids may be expected from large-scale plant operation.
3. The radioactive phosphorus, P^{32}, was added in an amount equal to approximately 0.5 μc. per feed, or an average of 1,200 disintegrations per minute per ml. This added activity resulted in the uptake of P^{32} by the activated sludge mixed liquor to a concentration roughly three times the feed in sludges B, C, and D. In sludge A, fed synthetic sewage with only 1 p.p.m.

TABLE IV.—Operating Data on the Uptake of P^{32} by Activated Sludge

Activated Sludge	A	B	C	D
Feed (twice per day)	Syn. sew.[1]	Syn. sew.[1]	Sewage[2]	Sewage[2]
B.O.D. load (lb./D/1,000 c.f.)	35	35	33	33
P^{31} added (p.p.m.)	1	3	0	3
P^{32} added (d.p.m./ml.)[3]	1,200	1,200	1,200	1,200
Aerator susp. sol. (p.p.m.)	2,100–2,500	1,800–2,200	2,500–3,100	2,800–3,100
Settl. range, S.V.I.	28–80	19–47	31–43	36–39
P^{32} in mixed liq. (d.p.m./ml.)[3]	8,600	4,240	3,880	3,670
Supernatant:				
Susp. solids (p.p.m.)	89	113	25	13
B.O.D. (p.p.m.)	15	20	9.5	9.0
P^{32} (d.p.m./ml.)[3]	270	705	744	800
pH	6.9–7.5	6.9–7.6	6.8–7.8	6.8–7.8
Removal of P^{32}:				
Range (%)	52–88	12–77	8–63	−11–56
Average (%)[4]	78	43	38	35

[1] Feed of 0.3 g. wheat flour and 0.1 g. dextrose in 800 ml. tap water; B.O.D., 336 p.p.m.
[2] Feed of 800 ml. domestic sewage—Estimated B.O.D. of 320 p.p.m.
[3] Disintegrations per minute per ml.
[4] Weighted average for a two-week period.

stable phosphorus, the uptake of P^{32} by the sludge was much greater and accumulated in the mixed liquor to a concentration equal to six to seven times the concentration in the feed.

4. The over-all removal of P^{32} by the activated sludge was somewhat erratic from day to day. In sludge A, fed synthetic sewage with a minimum of phosphate, the removal of P^{32} varied from 52 to 88, or an average of 78 per cent of the feed. In sludge B, fed synthetic sewage with 3 p.p.m. of stable phosphate-phosphorus, the over-all removal varied from 12 to 77, or an average of only 43 per cent. In the sewage-fed sludges the P^{32} removal varied from less than zero to 63, or an average of 35 to 38 per cent.

Fluctuations in Uptake of P^{32}

The uptake of radioactive phosphorus during each feeding by the activated sludges fed on flour-dextrose is presented in Figure 2. The raw counting data on small samples were converted to disintegrations per minute (d.p.m.) in the 700 to 800 ml. of supernatant withdrawn before each feeding. Since the counting was made following the decanting of supernatant, the radioactivity of feed and supernatant was corrected for decay to the time of decanting. Figure 2 shows the amount of P^{32} added at each feeding and the total activity found in the supernatant. The amount of P^{32} appearing in the supernatant of the sludge fed a deficiency (1 p.p.m.) of stable phosphorus required for good process control was usually much less than half the amount of P^{32} in the supernatant from the sludge fed 3 p.p.m. stable phosphorus. The effect of no feeding over the week end, particularly with a deficiency of phosphorus in the feed, is shown on the seventh and fourteenth days of the experiment. The Monday morning supernatants contained three times as much radioactive phosphorus as the Friday afternoon samples. This deterioration of the sludge probably would not occur in a continuously fed system. A similar plot of the supernatant results from sludges fed sewage with or without phosphate fortification presented a scatter diagram of wide fluctuations. During the second week of operation, when it appeared that equilibrium conditions had been reached, the phosphate fortified sewage sludge passed slightly more P^{32}.

Distribution of P^{32} in Activated Sludge

The distribution of P^{32} in activated sludge was determined weekly or biweekly. In preparing a balance at the end of a particular period, the P^{32} concentrations in the feed, supernatants, and sludges were all corrected for decay to the end of each period. Since P^{32} has a half-life of 14.3 days, the decay amounts to a loss of roughly 5 per cent of residual radioactivity in 24 hr. The results of the balances are presented in Table V. Unfortunately, the radioactivity of the sludge wasted per day was assayed infrequently, so that a significant error of this estimation may have occurred.

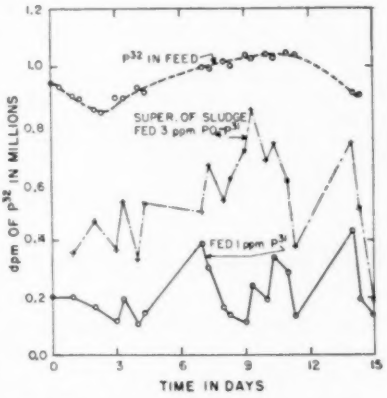

FIGURE 2.—Fluctuations in the radioactivity (P^{32}) of supernatants from activated sludge fed synthetic sewage (flour-dextrose) fortified with stable phosphate (P^{31}). P^{32} in feed = 855,000 to 1,040,000, or an average of 960,000 disintegrations per minute in an aerator volume of 1 l.

TABLE V.—Distribution of Radioactive Phosphorus in Activated Sludge

Item	Activated Sludge			
	A	B	C	D
Feed	Syn. sew.	Syn. sew.	Sewage	Sewage
P^{31} in feed (p.p.m.)	1	3	0	3
(*a*) P^{32} Balance after One Week (Millions of d.p.m.)				
1. Added in feed, less decay	6.96	6.96	6.96	6.96
2. In supernatant	1.18	2.25	3.01	2.96
3. In mixed liquor at end	4.87	3.41	2.10	2.54
4. Calc. to be in waste sludge 1 − (2 + 3)	0.91	1.3	1.85	1.46
5. Found in wasted sludge	1.37	0.57	0.35	0.43
6. Unaccounted for (4 − 5)	−0.46	0.73	1.5	1.03
(*b*) P^{32} Balance after Two Weeks (Millions of d.p.m.)				
1. Added in feed, less decay	9.45	9.45	9.45	9.45
2. In mixed liquor at start	3.30	2.31	1.42	1.72
3. In supernatant	2.41	6.37	6.23	6.65
4. Mixed liquor at end	8.4	3.96	3.35	3.00
5. Calc. to be in waste sludge (1+2) − (3+4)	1.94	1.43	1.29	1.52
6. Found in wasted sludge	2.04	0.91	0.67	0.68
7. Unaccounted for (5 − 6)	−0.10	0.52	0.62	0.84

Radioactive Density of Activated Sludge

When phosphate for activated sludge metabolism is deficient in the food, such as in sludge A, a much higher percentage of the radioactive phosphorus is assimilated and increases the radioactivity of the activated sludge. This is shown in the balance after two weeks (Table V b, Item 6) and, for purposes of emphasis, in Table VI, where the radioactive density of the sludges has been calculated per gram of dry sludge solids and per kilogram of 3 per cent settled sludge (Items 4 and 5), respectively. Table VI shows that the radioactivity of sludge A (fed a deficient supply of P^{31}) increased to 1.65 μc. per gram of dry sludge solids in two weeks, whereas sewage-fed sludge accumulated a radioactivity density of only 0.6 μc. per gram or less. Sludge B, fed flour-dextrose fortified with 3 p.p.m. P^{31}, accumulated a specific radioactivity in two weeks of 0.99 μc. per gram.

Uptake of I^{131} by Activated Sludge in the Presence of Stable Iodine

Studies on the uptake of radioactive iodine by activated sludge fed sewage or synthetic sewage containing stable iodine were performed in a two-week period similar to the radioactive phosphorus studies. Since it had been recommended (1) that radioactive iodine wastes might be discharged to sewers, provided that 1 g. of potassium iodide was added to each millicurie of radioiodine, the sewage and synthetic sewage used in these studies were dosed with 1 to 3 p.p.m. of stable iodine (I^{127}) as the potassium salt and 0.5 μc. I^{131}. The operating data are summarized in Table VII. Sludges E and F were fed flour-dextrose fortified with 2.0 to 2.5 p.p.m. phosphorus; sludges G and H were fed sewage. Sludges E and G received 1 p.p.m. stable iodine, while sludges F and H received 3 p.p.m. stable iodine. The concentration of aerator solids was maintained between

TABLE VI.—Radioactive Density of Activated Sludge

Item	Activated Sludge			
	A	B	C	D
Feed	Syn. Sew.	Syn. Sew.	Sewage	Sewage
P^{31} in feed (p.p.m.)	1	3	0	3
(*a*) After One Week of Operation				
1. Aerator susp. solids (g.)	2.26	2.13	3.16	2.83
2. P^{32} in sludge (d.p.m. × 10^6)	4.87	3.41	2.1	2.54
3. P^{32} in sludge (μc.)	2.2	1.54	0.95	1.15
4. P^{32} (μc./g. sludge solids)	0.97	0.72	0.3	0.4
5. P^{32} (μc./kilo. of 3% sludge)	29.2	21.6	9.0	12.0
(*b*) After Two Weeks of Operation				
1. Aerator susp. solids (g.)	2.29	1.80	2.54	2.79
2. P^{32} in sludge (d.p.m. × 10^6)	8.4	3.96	3.35	3.00
3. P^{32} in sludge (μc.)	3.78	1.78	1.51	1.35
4. P^{32} (μc./g. sludge solids)	1.65	0.99	0.60	0.48
5. P^{32} (μc./kilo. of 3% sludge)	48.5	29.7	17.8	14.5

3,400 and 6,300 p.p.m. in sludges E and F, so that the B.O.D. loading of 44 lb. per day per 1,000 cu. ft. was relatively low per unit of mixed liquor suspended solids. On the other hand, the B.O.D. loading of sewage-fed sludges G and F was comparable to the phosphate studies. The radioactive iodine added was 1,370 d.p.m. per ml. of feed. The results show the radioactivity in the supernatants averaged 1,230 to 1,350 d.p.m. per ml., indicating a removal of I^{131} by activated sludge of 10 per cent or less. This value is within the experimental error of the radioactive iodine determination. However, it will be noted that the radioactive iodine found in mixed liquor was higher than the feed and indicates a low but significant accumulation of radioactive iodine in activated sludge fed nutrients containing 1 to 3 p.p.m. of stable iodine.

Experiments on the removal of I^{131} in the absence of stable iodine have not

TABLE VII.—Summary of I^{131} Operating Data on Activated Sludge

Item	Synthetic Sewage Feed[1]		Sewage Feed[2]	
	Sludge E	Sludge F	Sludge G	Sludge H
B.O.D. load (lb./1,000 c.f./day)	44	44	33	33
P^{31} added (p.p.m.)	2.0–2.5	2.0–2.5	—	—
I^{127} added (p.p.m.)	1.0	3.0	1.0	3.0
I^{131} added (d.p.m./ml.)	1,370	1,370	1,370	1,370
Aerator susp. solids (p.p.m.)	4,000–6,300	3,400–4,800	1,300–2,000	2,000–2,900
Volume of sludge[3] (ml./l.)	140–220	160–270	40–90	50–105
I^{131} in mixed liq. (d.p.m./ml.)	2,140–2,500	1,710–2,240	1,410–1,840	1,480–2,130
I^{131} in supernatant (d.p.m./ml.)	1,350	1,340	1,230	1,230
I^{131} removal by act. sl. (%)	1.4	2.7	10.3	10.0

[1] Feed of .375 g. of flour and .125 g. of dextrose given twice a day.
[2] Feed of 800 ml. of sewage twice a day.
[3] Milliliters of sludge after 30 min. settling.

been completed. Pilot trickling filter studies conducted by Carter (2) indicated a removal of 85 per cent or more of carrier-free I^{131} in weak sewage when the dosage rate was 2 m.g.d. in a 6-ft. filter and the level of I^{131} was 1,000 c.p.m. per ml.

Absorption of Radioactivity from Mixed Fission Product by Activated Sludge

Two preliminary experiments were made on the absorptive capacity of activated sludge for 3-month old mixed fission product. An analysis of fission product of the age used from data by Tompkins, Khym, and Cohn (15) is presented in Table VIII. The experiments consisted of adding radioactive fission product to 500-ml. volumes of mixed liquor and aerating 4 hr. or more. Periodically, 50-ml. samples were settled for 30 min. Ten-ml. samples of the supernatant were collected, dried, and counted in an internal counter. The efficiency of counting was found to be 73 per cent of the true disintegration rate. A summary of the data is presented in Table IX. The results show that 40 to 50 per cent of the mixed fission product radioactivity was absorbed by activated sludge in 1 hr. or less and that 75 to 77 per cent was absorbed in 4 hr. of aeration.

TABLE VIII.—Relative Amounts of Major Radioactive Elements in Fission Product After 3 Months[1]

Element	Atomic No.	Half-Life[2]	Relative Abundance (%)
Strontium	89	53 d	9.9
Strontium-Yttrium	90	25 y	1.5
Yttrium	91	57 d	13.0
Zirconium	95	65 d	15.4
Niobium	95	35 d	25.1
Ruthenium	103	42 d	7.2
Ruthenium	106	365 d	1.2
Rhodium (daughter)	106	30 s	1.2
Cesium	137	33 y	0.7
Cerium	141	28 d	4.9
Cerium	144	275 d	15.7
Promethium	147	3.7 y	2.9
Total	—	—	98.7

[1] Calculated from Tompkins, Khym, and Cohn (15) data.
[2] s = seconds, d = days, y = years.

Discussion

The removal of radioactivity by activated sludge and the trickling filter may be effected by one or a combination of mechanisms. The more important possibilities appear to be:

1. The aerobic microbiological destruction of complexing and sequestering agents associated with radioactive wastes. Other mechanisms of removal may then occur. This would seem to be

TABLE IX.—Absorption of Mixed Fission Product by Activated Sludge

Aeration Time (hr.)	Radioactivity (d.p.m./ml.)					
	Sludge A[1]			Sludge B[2]		
	Added	In Super.	Absorbed (%)	Added	In Super.	Absorbed (%)
0	945	—	—	4,700	—	—
0.02	—	—	—	—	2,225	50
0.33	—	650	31	—	—	—
1	—	535	43	—	—	—
3	—	270	71	—	—	—
4	—	220	77	—	1,125	75
24	—	120	87	—	—	—

[1] 1,960 p.p.m. suspended solids.
[2] 1,820 p.p.m. suspended solids.

the most important function of activated sludge for the removal or the preparation for the removal of radiocolloids in laboratory decontamination, laundry, and some process wastes.

2. The physicochemical absorption of radioactive ions, colloids, and suspended matter by the zoogleal mass in activated sludge or on filters. For this mechanism to be effective, it may be presumed that complexing agents and detergents must be destroyed or eliminated to a large degree as stated above.

3. The utilization or synthesis of elements required in the growth and propagation of activated sludge or zoogleal masses on filters. Radioactive mineral nutrients will be utilized by activated sludge in proportion to the abundance of total like elements of similar availability. Thus, if the mineral nutrient, such as phosphorus, is deficient in the feed for activated sludge, a high removal of radiophosphorus may be anticipated. However, in the presence of an abundant supply of non-radioactive available phosphate, a low percentage removal of radioactive phosphorus may be anticipated. In sludges A and B, the average radioactive phosphorus added was 960,000 d.p.m. or 1.2×10^{-10} mg. per feed, as against 1 and 3 mg. of non-radioactive phosphate-phosphorus, respectively, and exclusive of an estimated 0.3 mg. of phosphorus in the wheat flour and minute amounts in the tap water. Thus, only traces of total phosphorus in the activated sludge feed were radioactive. However, an average of 78 per cent of the radioactive phosphorus was removed in sludge A because there was a deficiency of total phosphorus.

In the case of the iodine studies the radioactive iodine per feed amounted to 3×10^{-9} mg., as against the 1 or 3 mg. of non-radioactive iodine added. In this case the sludge has an affinity for total iodine (which is not necessarily for metabolic purposes) and the preponderance of non-radioactive iodine results in low removal of radioactive iodine.

General Summary and Conclusion

In conclusion, it may be stated that the maximum removal of radioactivity that may be expected by treatment in biological systems is about 95 per cent. Consequently, such systems can be used only on relatively low-level wastes. It can also be generalized that:

1. Biological treatment is not indicated for soluble isotopes that are not utilized or readily absorbed on biological floc (as, for example, I^{131}).

2. Biological processes are not satisfactory for the treatment and removal of isotopes of elements which are isotopically diluted by constituents in sewage. This is true even though the element is required for microbial propagation and normal metabolism of the sludge. The P^{32} experiments illustrate this.

3. Biological treatment may be used for the removal of isotopes, such as plutonium, which have no isotopic dilution and which are easily absorbed by the zoogleal floc under proper conditions.

4. Biological treatment may be used on waste containing, in addition to the radioactive isotope, organic materials which sequester or prevent chemical treatment for the removal of the activity. In this case, the biological system is used simply to remove by oxidative assimilation the organic sequestering constituents. Following such removal the effluent may be chemically treated by flocculation, carrier-precipitation, or other methods to remove the radioactivity.

Acknowledgment

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INOCULATION STUDIES IN B.O.D. DETERMINATION ON SEWAGE AND PULP MILL WASTE*

By Raymond Zehnpfennig and M. Starr Nichols

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Since the introduction of the B.O.D. determination as a standard method for the examination of sewage and wastes, it has been frequently observed that concordant results are not always obtained when a given sample of sewage is analyzed in different laboratories, even when reasonable precautions are taken to minimize biological action in the sample prior to the time of analysis.

In determining the B.O.D. of standard substances such as glucose and peptone with fresh settled sewage as inoculum, it has also been observed that the B.O.D. fluctuates widely when sewages from different sources are used as inoculum (1) and with samples of sewage from the same source collected at different times.

It is recognized that the attainment of a biochemical oxygen demand approaching the theoretical ultimate demand is dependent on a biological relation between the bacteria and the protozoa, the bacteria using the major portion of the oxygen while the protozoa hold the bacterial numbers below the limiting count by using them as food. This protozoal action permits continued growth and oxidation by the bacteria and at the same time returns organic constituents of the bacteria to the substrate again to be acted on by the bacteria (2). Unless, however, there is a check on the multiplication of protozoa, the number of protozoa in the sewage dilution increases as oxidation proceeds, and the bacteria are eventually reduced in numbers to a point at which the rate of oxidation is determined by the number and reproduction rate of the bacteria, rather than by the concentration of organic food material (2). Since this latter rate is slow, the reaction is no longer of the first order, but becomes linear, and the calculated ultimate B.O.D. is lower than that expected on the basis of organic matter known to be present when a standard substrate of known composition is used. The time at which this reduction in bacterial numbers occurs, and therefore the apparent ultimate B.O.D., is determined by the original number of viable protozoa, all other conditions being equal.

Since it is virtually impossible to control the number of protozoa in the original inoculum by practical methods, attention has been turned in this laboratory to the use of protozoa-free bacterial cultures as inoculum.

The ideal procedure would be to use a single species of bacteria as inoculum, and to sterilize the sample before inoculation. Experiments in this direction, using several bacterial cultures isolated from sewage, as well as stock cultures of *Aerobacter aerogenes*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Serratia marcescens*, and *Proteus vulgaris*, showed that under the conditions of the B.O.D. determination these bacteria could oxidize either carbohydrates or proteins, but were unable to attack both. The maintenance of a mixed culture of known organisms capable of attacking all substrates is impractical except as a research procedure. For this

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reason, the inoculum has been prepared by inoculation of sterile settled sewage with a mixture of organisms obtained by the filtration of fresh sewage to remove protozoa, and incubation of the mixture to obtain a good growth of sewage bacteria. This inoculum has the advantage of causing a rapid oxidation to a limiting value, which is attained for practical purposes in not more than two days. After this time, oxidation proceeds relatively slowly, so that no great advantage is obtained by further prolonging the oxidation period. The final degree of oxidation thus obtained is less than that obtained by the use of fresh settled sewage as inoculum. However, if it is considered that the 5-day B.O.D. is ideally only 68 per cent of the ultimate demand, this is only an apparent objection due to usage.

The experiments described herein compare the reproducibility of the 2-day and 5-day B.O.D. using filtered inoculum with that of the 5-day B.O.D. using settled sewage inoculum. Samples from one batch each of autoclaved sewage and of autoclaved dilute pulp mill waste were used as substrates throughout the entire series of determinations.

Preparation of Samples

Raw sewage was collected at the Brittingham Park pumping station of the Madison (Wis.) Metropolitan Sewage District. After settling for 1 to 2 hr., the supernatant was drawn off, thoroughly mixed, and distributed into Erlenmeyer flasks in 200-ml. portions. These were autoclaved at 15-lb. pressure for 15 min., and stored at room temperature until used.

A sample of digester liquor from a sulfite pulp mill was diluted 1 : 100 with distilled water, neutralized to pH 7.2, distributed into Erlenmeyer flasks, and autoclaved as previously described. All B.O.D. determinations were made on the same lot of autoclaved samples of both sewage and pulp mill waste.

Preparation of Inoculum

Fresh sewage was collected between 10 and 12 AM on each day that the 5-day B.O.D. determinations were to be set up. After settling for 1 to 2 hr., a portion of the supernatant was reserved for use as inoculum for the standard method 5-day B.O.D., while a second portion was passed through a fine-pore sintered glass filter to remove protozoa. To 100-ml. portions of the autoclaved sewage and of dilute pulp mill waste, 1-ml. portions of this filtrate were added. These inoculated samples were then incubated at 20° C. The sewage was incubated for 24 hr., the pulp mill waste for 48 hr.

Determination of B.O.D.

Of the well-mixed autoclaved sewage, 10-ml. portions were pipetted into each of six B.O.D. bottles. To each bottle, 1 ml. of well-mixed fresh settled sewage was added as inoculum. Six blanks were prepared, each with 1 ml. of the fresh settled sewage as inoculum. The bottles were filled with ammonia-supplemented Formula C dilution water.

On the following day, 20-ml. portions of the autoclaved settled sewage were pipetted into each of six bottles, and 1 ml. of the incubated sewage-sewage filtrate inoculum was added to each bottle. Six blanks were set up, using 1 ml. of the same inoculum per bottle. The bottles were filled with ammonia-supplemented Formula C dilution water.

The same procedure was followed with the 1 : 100 dilution of the pulp mill waste, with the exception that the protozoa-free inoculum was incubated two days before use. Both 2-day and 5-day B.O.D. determinations were made using the sewage filtrate-pulp mill waste inoculum.

The samples inoculated with fresh settled sewage were incubated 5 days as

TABLE I.—Reproducibility of 5-Day and 2-Day B.O.D. of Autoclaved Sewage with Filtered and Unfiltered Inoculum

Date	5-Day B.O.D.[1] Settled Sewage Inoculum	2-Day B.O.D.[1] Filtered Sewage Inoculum
7–12	156	90.6[2]
7–13	150	90.5
7–16	152	91.7
7–18	138	88.1
7–20	158	87.1
7–23	141	88.5
7–25	128	88.8
7–27	132	95.5
7–30	135	87.9
8–1	133	58.4[3]
8–3	174	87.7
8–6	153	91.0
Mean	145	89.7
Standard deviation:		
Groups	32.9	6.25
Individuals	6.68	2.60
Variance ratio	24.2[4]	6.2[4]
Coeff. of variation (%):		
Groups	22.7	6.9
Individuals	4.6	2.9

[1] Mean of six determinations.
[2] 3-day B.O.D.; not included in analysis.
[3] 1-day B.O.D.; not included in analysis.
[4] Below 1 per cent probability level.

in the standard method (3). The sewage samples inoculated with the filtered sewage inoculum were incubated 2 days. One-half of the B.O.D. dilutions of the dilute pulp mill waste and blanks inoculated with the filtered sewage-pulp mill waste inoculum were incubated 2 days, the other one-half for 5 days. The experiments with sewage as substrate were repeated on each of 12 days, and that with dilute pulp mill waste on each of 10 days. The results of the B.O.D. determinations and the statistical analysis are shown in the Tables I and II.

Discussion

The coefficients of variation for individuals show a satisfactory reproducibility (2.2 to 4.6 per cent) within a given day for all the procedures and substrates used. In comparing the results of determinations made on the same sample on different days, the reproducibility of the 5-day B.O.D. is the lowest of all the methods used. In the case of pulp mill waste, however, there is little choice between the 2-day procedure with filtered inoculum and the 5-day procedure with settled sewage inoculum. In this case, the 5-day procedure with filtered inoculum shows up as the best.

With sewage as the substrate, there is no doubt of the superiority of the 2-day procedure. The variability of the 5-day procedure with settled sewage inoculum is shown to be more than three times that of the 2-day procedure with filtered sewage inoculum. The 2-day value is lower than the 5-day value, mainly because of the absence of protozoal action.

TABLE II.—Reproducibility of 5-Day and 2-Day B.O.D. of Dilute Autoclaved Pulp Mill Waste with Filtered and Unfiltered Inoculum

Date	Filtered Inoculum		Sett. Sewage Inoc.
	2-Day B.O.D.[1]	5-Day B.O.D.[1]	5-Day B.O.D.[1]
11–19	76.9	84.8	110
11–23	79.0[2]	90.0	115
11–26	76.0	84.5	116
11–28	—	84.6	118
11–30	79.0	87.6	108
12–2	71.9	93.1	119
12–4	38.4[3]	88.0	—
12–6	78.9	89.1	110
12–10	83.5	92.5	125
12–12	75.0	87.1	123
Mean	77.3	88.1	116
Standard deviation:			
Groups	8.8	7.6	14.6
Individuals	1.69	3.7	2.66
Variance ratio	26.8[4]	4.25[4]	30.0[4]
Coeff. of variation (%):			
Groups	11.4	8.63	12.5
Individuals	2.19	4.20	2.3

[1] Mean of six determinations.
[2] 3-day B.O.D.; not included in analysis.
[3] 1-day B.O.D.; not included in analysis.
[4] Below 1 per cent probability level.

The data here presented do not provide an explanation for the high day-to-day variability of the standard 5-day B.O.D. as compared to the 2-day value. A difference in activity of protozoa, leading to variations in the reaction rate and final degree of oxidation, is highly probable. Finally, work on the aging of filtered cultures, not here reported, shows that certain bacteria, notably those which attack carbohydrates, disappear as the culture is aged. It is therefore reasonable to believe that the variations in 5-day B.O.D. from day to day are due to differences in numbers and kinds of both protozoa and bacteria in the inoculum.

Conclusions

1. The conventional 5-day B.O.D. is reasonably reproducible only for a single inoculum, and is not reproducible from day to day. This implies that the biota of sewage varies from day to day, and that a sewage which gives low values when used as inoculum for a substrate of known or fixed concentration, may itself have an apparent B.O.D. lower than would be expected on the basis of organic matter present. The 5-day B.O.D. is, therefore, dependent not only on the concentration of organic matter, but on the nature of the biota as well.

2. Filtration of sewage to remove protozoa, and incubation of the filtrate in autoclaved sewage or autoclaved dilute pulp mill waste, yields a bacterial inoculum which gives fairly reproducible results in two days. While oxidation continues at a slow rate after this time, as in the standard method, no advantage is obtained by increasing the period of incubation.

3. The improved reproducibility of the B.O.D. in the presence of a sewage flora prepared in this manner indicates that the variability of the 5-day B.O.D. is probably caused in part by the presence of varying numbers and kinds of protozoa, and also in all probability by the fact that the bacteria present in greatest numbers in fresh sewage are not necessarily those most active in its oxidation. The preparation of an inoculum of filtered sewage in autoclaved sewage insures the preponderance of bacteria which will oxidize sewage.

4. Since the purpose of the B.O.D. determination is to obtain a definite, reproducible fraction of the ultimate B.O.D., the 2-day procedure with a bacterial inoculum fulfills this purpose more satisfactorily than does the 5-day B.O.D., although the values obtained are numerically lower.

5. Since the various criteria of oxygen consuming capacity are variable, and, in the case of B.O.D. and chemical oxygen consumed, do not measure the same substances, any conversion factors between the values obtained by the different procedures must be indefinite. In Table III are shown the calculated

TABLE III.—Comparison of 2-Day and 5-Day B.O.D. of Various Substrates with the Calculated Chemical Oxygen Consumed

(1) Substrate	(2) Calculated Chemical Oxygen (p.p.m.)	(3) Calculated 5-Day B.O.D. (p.p.m.)	(4) 2-Day B.O.D. (p.p.m.)	(5) $\frac{\text{Col. 2}}{\text{Col. 4}}$
0.03% glucose	320	228	134	0.418
0.03% casein	463	316	190	0.411
0.03% starch	356	242	142	0.399
0.03% phenol	714	485	412	0.578
0.03% tryptone	463	316	161	0.348
0.03% linseed oil fatty acids	879	596	359	0.409

chemical oxygen consumption, the calculated 5-day B.O.D. (68 per cent of the calculated chemical consumption), and the experimental values for 2-day B.O.D. of six known substrates.

Acknowledgment

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SOUTH'S INDUSTRIAL WASTES PROBLEMS TO BE SUBJECT OF REGIONAL MEETING

The Southern Association of Science and Industry recently announced that a special two-day regional conference will be held in New Orleans on April 20–21, 1953, to cope with problems of air and stream pollution. The conference will bring together experts in all phases of industrial waste disposal and utilization to work out a sound program for the region's future guidance.

"Clean air and clean streams are a great Southern resource—we want to use them without abusing them," SASI President James F. Crist said in announcing plans for the conference. "Our objective is to continue the South's rapid industrial development without accumulating serious pollution problems similar to those that now exist in regions which were industrialized without adequate planning," he said.

The SASI program will focus attention on economic, technical, and social aspects of industrial wastes handling. Industrial leaders, government officials, research experts, and community representatives will participate. All sessions will be open to the public.

The tentative plan is to devote the first day to stream problems and the second to atmospheric problems. Speakers will include some of the nation's top men in the industrial wastes field.

Further information on the conference may be obtained from Southern Association of Science and Industry, 5009 Peachtree Road, Atlanta, Ga.

COLOR IN INDUSTRIAL WASTES *

IV. Effect of Light on Certain Wastes

By Willem Rudolfs and William D. Hanlon

Sunlight is an effective agent for the bleaching of color in natural reservoir water supplies (1). The monthly color reductions realized varied from approximately 50 per cent at the surface of the water to 1 per cent at a depth of 10 ft., the effectiveness decreasing rapidly with depth. Should this same factor be effective with industrial waste solutions, appreciable color reductions could be expected in lagoons, lakes, ponds, and streams. This study was undertaken to determine the effect of sunlight and ultraviolet light on the color characteristics of rag cooking liquor, sulfite cooking liquor, gum, and yeast wastes, and also to determine the effect of industrial waste solutions on the temperature rise of stream waters as a result of sunlight absorption.

Sunlight

Samples of the various raw wastes were diluted and adjusted to pH 7.0 (NaOH or H_2SO_4). Samples were exposed to direct sunlight in a 7- by 9-in. white porcelain tray for 118 hr. during the period from September 9 to November 11, 1951. At selected time intervals samples were withdrawn, diluted 1:1 with distilled water, adjusted to pH 7.6, and filtered for color determinations. Control samples were kept in the shade, and their color characteristics determined at the beginning and end of the total exposure period. All evaporation losses were compensated with distilled water throughout the exposure period.

The results (Figure 1) show that sunlight exposure decreased the purity of the yeast, rag, and gum wastes, and slightly increased the purity of the sulfite waste. The controls for the sulfite, yeast, and rag wastes showed very little color change in the total time. On the other hand, the purity of the gum waste color decreased 16 per cent during the exposure period, indicating that the color reduction was not solely the result of sunlight. In relation to the controls, the purity reductions of the yeast, rag, and gum wastes after 118 hr. of exposure were, respectively, 20, 36, and 18 per cent. The color reductions are probably not the maximum, and these values would possibly increase somewhat for exposures during the summer months when the sunlight would be more effective on horizontal surfaces. It is believed that the most effective light energy for color reduction originates in the ultraviolet region of the sunlight. The energy in both the visible and ultraviolet regions is sufficient to displace outer electrons from molecules, but larger displacements with greater energy occur in the ultraviolet region.

Ultraviolet Light

Rag Cooking Liquor Waste

Aliquots of a rag cooking liquor effluent (250 p.p.m. B.O.D.) from an activated sludge process were diluted (1:2.33), adjusted to pH 7.0, and exposed to ultraviolet radiation (2,537 Ångstroms) for varying periods. After exposure, all samples were adjusted to pH 7.6 and filtered for color determinations. Luminance values were also determined on sunlight-exposed samples at 7- and 30-day intervals, for the purpose of indicating the color stability of the samples after exposure.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

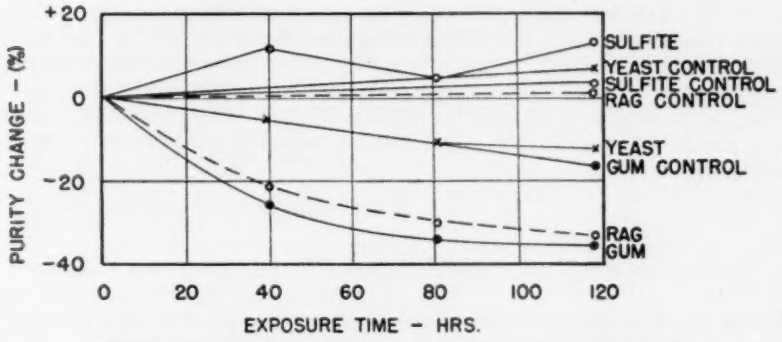

FIGURE 1.—Effect of sunlight on the purity of various wastes.

The curves of Figure 2 show that the rate of color reduction decreased with time and that the maximum -log luminance reduction for a 25-hr. ultraviolet light exposure period was approximately 55 per cent. The degree of color reduction is probably related to the intensity and wavelength of the light source.

Sulfite Cooking Liquor Waste

Samples of a waste sulfite cooking liquor effluent from an activated sludge process were diluted (1:1), adjusted to pH 7.0, exposed to ultraviolet radiation (2,537 Ångstroms), then adjusted to pH 7.6, and filtered for color determination.

The results (Table I) show that the ultraviolet light effected a color increase in the sulfite cooking liquor waste, the -log luminance increasing 28 per cent and the purity increasing 82 per cent.

Yeast Waste

Aliquots of a yeast waste effluent (60 p.p.m. B.O.D.) from an activated sludge process were diluted (1:1.94), adjusted to pH 7.0, exposed to ultraviolet radiation (2,537 Ångstroms), adjusted to pH 7.6, and filtered for color determinations. Color determinations were also made at 7- and 14-day intervals following the ultraviolet exposure periods.

The -log luminance curves (Figure 3) show a definite color reduction from the ultraviolet exposure. Further, the color continued to decrease during the 14-day period following the exposure. Why the color should continue to decrease is not understood, unless it was a result of flocculating pseudocolloidal particles.

As a result of the ultraviolet exposure, a fine coating had accumulated on the waste side of the quartz exposure tube. It was believed that this type of coating might significantly reduce the

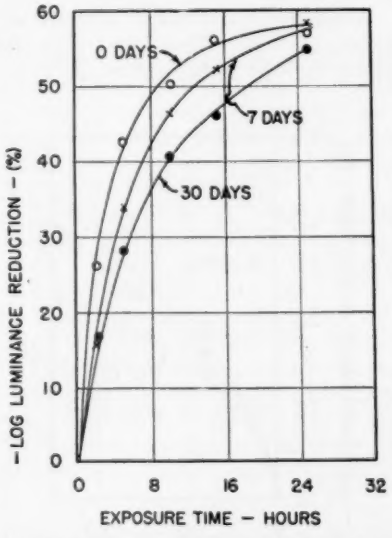

FIGURE 2.—Effect of ultraviolet light on the -log luminance of rag cooking liquor wastes.

TABLE I.—Effect of Ultraviolet Light on the Color Characteristics of a Sulfite Cooking Liquor Waste

No.	Vol. Act. Sl. Effl.[1] (ml.)	Vol. after Dilution (ml.)	Exposure Time (hr.)	Color Characteristics		
				Dominant Wavelength (millimicrons)	Luminance (%)	Purity (%)
1	50	100	0	581	41.6	55
2	50	100	25	580	32.4	100

[1] B.O.D. of feed to activated sludge, 3,000 p.p.m.

effect of the ultraviolet light by excessive absorption. To determine the effect of the coating on the degree of color reduction, the quartz tube was thoroughly cleaned (dichromate cleaning solution) and samples of the yeast waste were again exposed to the ultraviolet light for various periods.

The results show that there was an increase (35 to 40 per cent) in the effectiveness of the ultraviolet light after the tube had been cleaned. This would be an important factor to consider when applying this method of color reduction to large-scale operations.

Gum Waste

Aliquots of a gum waste effluent (165 p.p.m. B.O.D.) from an activated sludge process were diluted (1:0.67), adjusted to pH 7.0, and exposed to ultraviolet radiation (2,537 Ångstroms) for varying periods. Following the exposure, samples were removed for B.O.D. determinations and filtered for color determinations at pH 7.6. Color determinations were also made at 7- and 14-day intervals following the exposure periods.

The results (Figure 4) show that the color reduction (-log luminance) was directly related to the exposure time and also that there was a slight additional color decrease in the 14-day period following the exposure. After 40 hr. of exposure, the concentration of the colored substances had been reduced by approximately 46 per cent.

These results indicate that the color reduction obtained with sunlight was

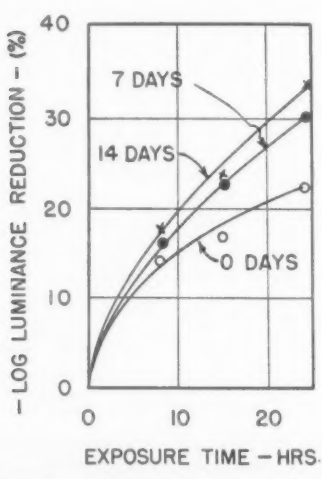

FIGURE 3.—Effect of ultraviolet light on the -log luminance of yeast waste.

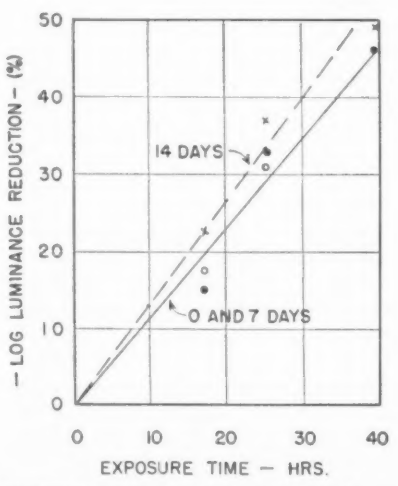

FIGURE 4.—Effect of ultraviolet light on the -log luminance of gum waste.

probably effected for the most part by the energy in the ultraviolet region. At present, artificial ultraviolet light is too costly for industrial waste color reduction; however, with modifications and improvements, the method may be feasible for practical use.

Light Absorption and Temperature Rise

Samples of raw sulfite cooking liquor, gum and yeast wastes, distilled water, and a raw surface water were exposed to the direct sunlight for 170 min. in white enamel trays and the temperature was recorded at selected time intervals throughout the exposure period. The data obtained showed no significant difference in the temperature rise of the distilled and raw surface water, but each of the wastes showed slightly higher temperature rises. The greatest temperature rise occurred in the yeast waste (Figure 5), with a maximum difference of 3° C. This is equivalent to a dissolved oxygen difference of about 0.5 p.p.m. At high oxygen concentration a decrease of 0.5 p.p.m. would be insignificant, but it is possible that at lower oxygen concentrations a loss of 0.5 p.p.m. oxygen might have some importance to fishlife.

A temperature rise in stream waters would also increase the rate of deoxygenation. For example, a 3° C. temperature rise would result in a 10 per cent increase in the biochemical oxidation velocity, k. However, a 3° C. temperature difference may be extreme because the various wastes were highly concentrated with respect to stream conditions. Furthermore, the temperature rise in the distilled water was probably low because it absorbs relatively more light in the longer or red wavelength regions and with increased depth the difference in temperature rise between the water and wastes would probably be less. For general stream conditions, it is not probable that the increase in temperature resulting from light absorption by industrial wastes in the stream would be significant, but it may be a minor factor in conjunction with the degree of pollution.

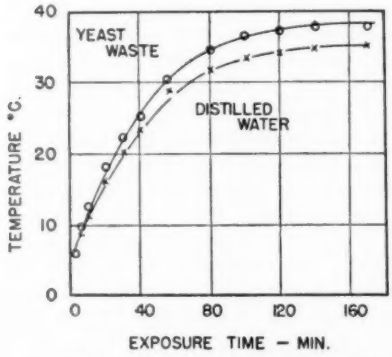

FIGURE 5.—Effect of sunlight on the temperature of yeast waste.

Summary and Conclusions

A study was made to determine the effect of sunlight and ultraviolet light on the color characteristics of various industrial wastes and to determine the effect of industrial wastes on the temperature rise of stream waters as a result of sunlight absorption. The following conclusions were drawn:

1. Sunlight and ultraviolet light (2,537 Ångstroms) are effective for reducing the color of rag cooking liquor, gum, and yeast wastes. On the other hand, they increase the color of a sulfite cooking liquor waste.

2. The presence of highly colored wastes in stream waters has little effect on the rate and extent of temperature rise due to sunlight absorption.

Acknowledgment

The investigation reported herein was supported by a research grant from the Division of Research Grants and Fellowships, National Institutes of Health, U. S. Public Health Service.

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WHITE WATER TREATMENT*

V. Aeration with Nonflocculent Growths

By Willem Rudolfs and Herman R. Amberg

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An aerobic treatment process which shows promise for the treatment of soluble organic waste (3) consists of aerating concentrated, soluble, nontoxic organic wastes in the presence of nonflocculent growth and returning to the raw waste the liquid in which the biological growth was dispersed. Heukelekian (3) has shown that with strong wastes up to 4,000 p.p.m. B.O.D., 70 to 80 per cent reductions were obtained, and with weaker wastes of not more than 1,000 p.p.m., 90 per cent.

Since the major portion of the B.O.D. is dissolved in white water it should lend itself readily to treatment by this aeration process.

Methods and Materials

The white water as received and the white water concentrate were subjected to a 4-hr. settling period to remove the settleable solids. The aeration units used were equipped with carborundum diffusers. Ammonium nitrate was added to the waste to give a B.O.D./N ratio of 20, and diammonium acid phosphate was added to give a B.O.D./P ratio of 60. When equilibrium conditions were established, samples were taken at 2-hr. intervals, centrifuged to remove suspended solids, and B.O.D. determinations made on the samples. The use of the centrifuge eliminated a sedimentation period prior to the B.O.D. determination, but the same degree of clarification could be accomplished by 0.5- to 1-hr. settling.

Aeration in Thermophilic Range

To determine whether stabilization of white water could be accomplished at a temperature in the thermophilic range and to determine the rates of stabilization at this temperature, experiments were conducted at 50° C. Since a number of board mills discharge wastes at temperatures as high as 50° C., it is of practical as well as theoretical interest to establish the possibility of treatment at this elevated temperature. The following feed-to-seed ratios were used: 0.33, 1.0, 3.0, and 9.0.

A thermophilic seed was developed by aerating domestic sewage at 50° C. and adding daily increments of white water for 2 weeks. Various quantities of acclimatized seed were added to settled white water. At the end of each 24-hr. aeration period withdrawals were made, the material was settled for 1 hr., B.O.D. was determined on the settled effluent, and the sludge was discarded. Since the effluent was turbid, coagulation with alum was tried to determine whether further B.O.D. reduction could be effected by coagulation. A 200-p.p.m. dose of alum was added, the pH adjusted to 6.5, and B.O.D. determinations were made on the clarified effluent. A summary of the results is given in Table I.

From 81 to nearly 88 per cent of the B.O.D. was reduced at feed-to-seed ratios of 0.33 to 9.0. A further B.O.D. reduction was accomplished by the use of a coagulant.

Figure 1 shows the rate of stabilization for a feed-to-seed ratio of 9.0 at

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

TABLE I.—Summary of Results at 50° C.

Feed to Seed Ratio	B.O.D. Load (lb. cu. ft./ day)	B.O.D.			Alum Treated	
		Infl. (p.p.m.)	Effl. (p.p.m.)	Red. (%)	B.O.D. (p.p.m.)	Red. (%)
0.33	0.0075	485	59	87.9	13	97.3
1.00	0.015	485	92	81.0	35	92.7
3.00	0.023	485	75	84.5	17	96.5
9.00	0.025	485	57	87.5	16	96.5

50° C. An aerobic thermophilic flora can be established in a relatively short time with domestic sewage. Approximately 75 per cent of the B.O.D. can be reduced in 6 hr. with an applied B.O.D. load of 0.097 lb. per day per cu. ft.; with aeration periods in excess of 6 hr. the rate of purification decreases. A disadvantage of the aeration process at the thermophilic temperature is the increase in turbidity, requiring coagulation for clarification of the effluent.

Effect of Temperature

Since aeration of white water with nonflocculent growths is feasible at 50° C., a study was made of the relationship between temperature and efficiency. The following temperatures were used: 20°, 30°, 35°, 40°, and 50° C.

To each aeration unit of white water 20 per cent (by volume) of sewage was added for seed. Daily additions of white water were made for 7 days before the rate curves were determined. Air was supplied at a rate of 1.5 cu. ft. per gallon of waste per hour. When equilibrium conditions were established, samples were taken at 2-hr. intervals for B.O.D. determinations.

The white water used for the 35° and 50° C. studies had an average initial B.O.D. of 432 p.p.m., and the rest of the units received a waste having an initial B.O.D. of 480 p.p.m.

The time required to establish an acclimatized seed and to obtain maxi-

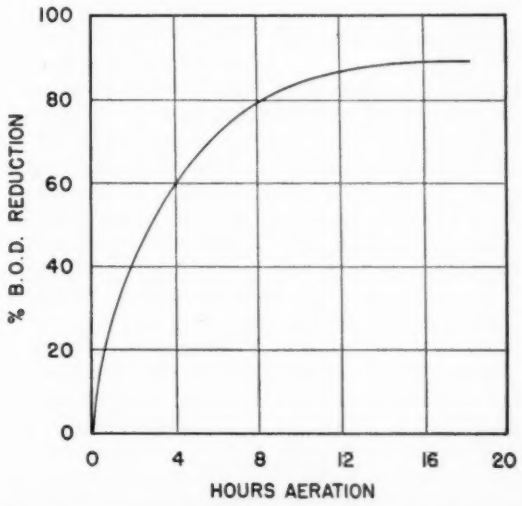

FIGURE 1.—Rates of white water purification at 50° C. with nonflocculent growth.

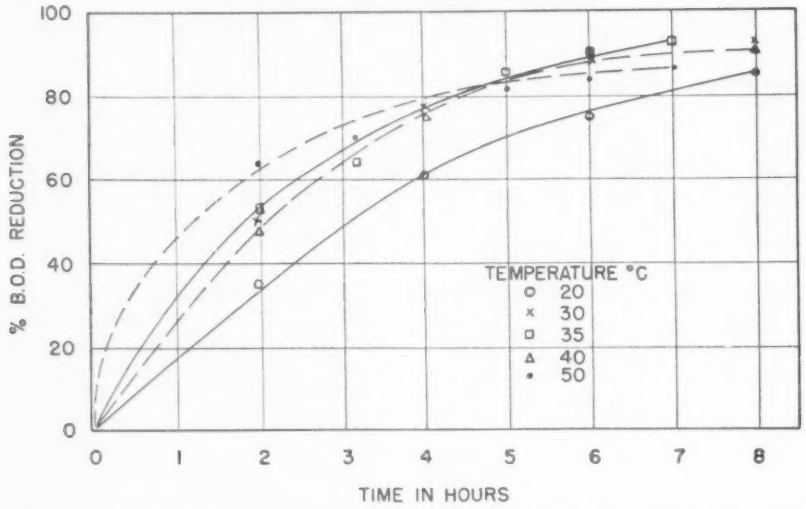

FIGURE 2.—Effect of temperature and time on B.O.D. reduction of white water treated with nonflocculent growth.

mum reduction of B.O.D. was found to be approximately 4 to 5 days.

Figure 2 shows the rate curves for the five different temperatures studied. At 50° C. the initial rate of oxidation was considerably greater than at the other temperatures, but the maximum B.O.D. reduction was 83 per cent. At temperatures of 30°, 35°, and 40° C. the differences in efficiencies were insignificant.

Figure 3 shows the B.O.D. reduction as a function of temperature at various time intervals. These curves clearly show the optimum temperature to be between 30° and 40° C. in the mesophilic range. When B.O.D. reductions below 80 per cent are desired, the thermophilic temperature is very efficient.

Figure 4 shows the B.O.D. loads that can be applied at the various temperatures to obtain a given B.O.D. reduction. For a B.O.D. reduction of 60 per cent approximately 0.22 lb. of B.O.D. may be applied per cubic foot of aerator capacity at the optimum mesophilic temperature, and 0.31 lb. B.O.D. per cubic foot per day at a temperature of 50° C. To obtain a B.O.D. reduction of 80 per cent the loading applied was 0.135 lb. B.O.D. per cubic foot per day at a temperature of 30° C. The suspended solids in the aeration unit ranged from 60 to 100 p.p.m. and settled readily within 30 min.

Effect of Rate of Aeration

The optimum temperature for aeration of white water with nonflocculent growths was found to be between 30° and 35° C. Using 30° C. as the approximate optimum temperature, experiments were conducted to determine the effect of the rate of aeration upon this treatment process. The aeration rates used varied from 0.07 to 6.8 cu. ft. per gallon of waste per hour. The procedure fellowed was the same as in the previous experiment.

Figure 5 shows the rate curves for the various aeration rates used. Obviously, the efficiency is greatly reduced when aeration rates are less than 0.25 cu. ft. per gallon per hour.

Results pertaining to the effect of time and rate of aeration on the percentage B.O.D. reduction of white wa-

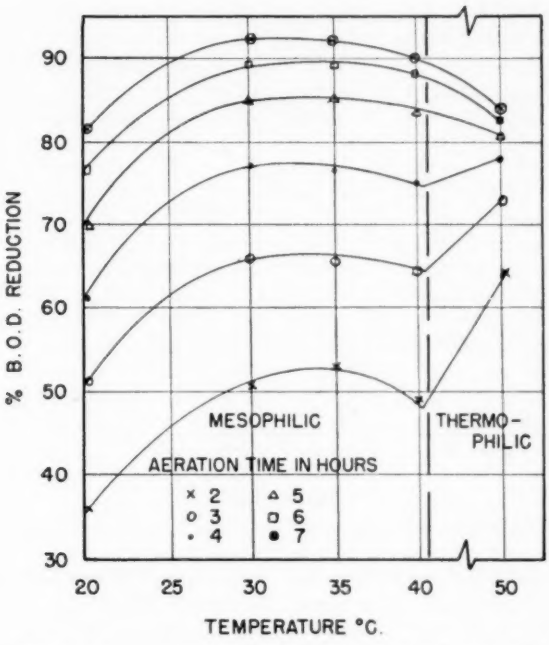

FIGURE 3.—Effect of temperature and aeration time on percentage B.O.D. reduction.

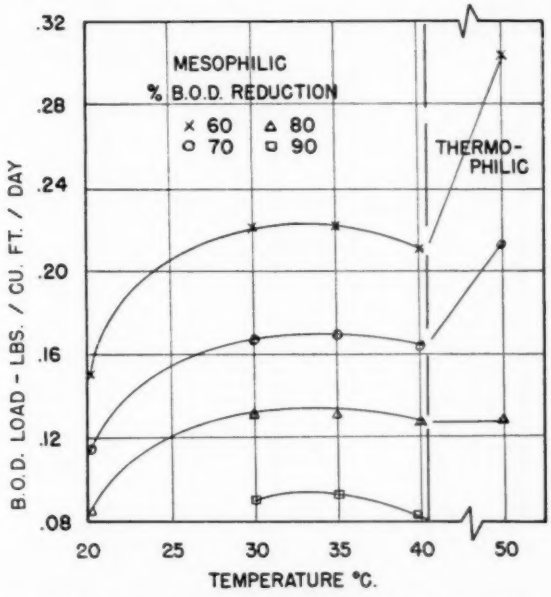

FIGURE 4.—Effect of temperature on B.O.D. loading for specific percentages of B.O.D. reduction.

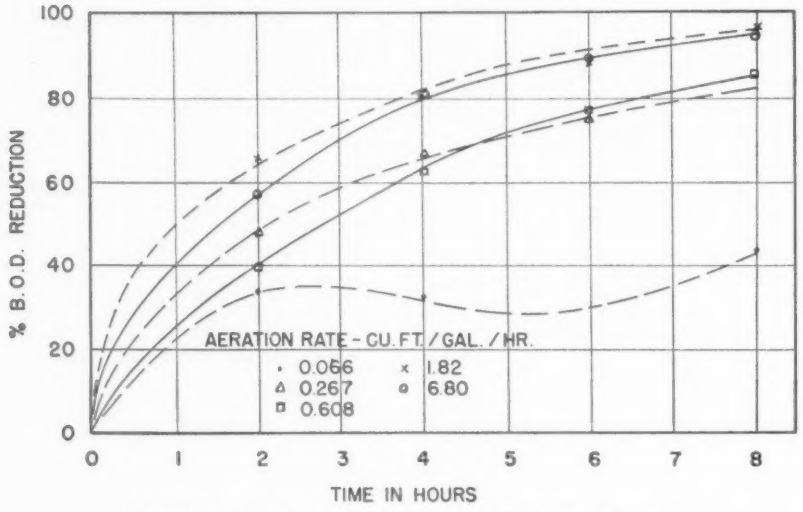

FIGURE 5.—Effect of rate of aeration on B.O.D. reduction.

ter with an initial B.O.D. of 400 p.p.m. show a rapid decrease in efficiency when the aeration rate is below 0.25 cu. ft. per gallon per hour. When aeration rates ranging from 0.25 to 1.8 cu. ft. per gallon per hour were used, the efficiency was a linear function of the aeration rate.

The most efficient aeration rate from the standpoint of air economy is 0.25 cu. ft. per gallon per hour. Lower aeration rates result in a rapid drop in efficiency, but a gradual increase in efficiency occurs when the aeration rate is increased from 0.25 to 1.8 cu. ft. per gallon per hour. Aeration rates in ex-

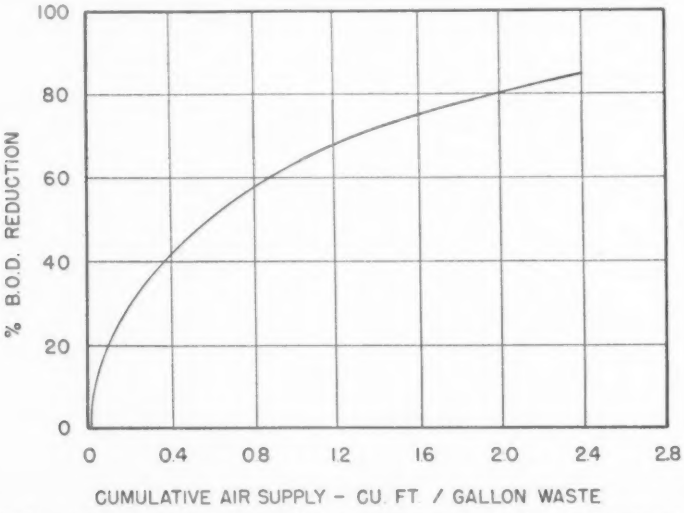

FIGURE 6.—Relation between air supplied at constant rate of 0.267 cu. ft. per gal. per hr. and B.O.D. reduction.

cess of 1.8 cu. ft. per gallon per hour do not materially improve the efficiency. To accomplish a B.O.D. reduction of 80 per cent, using an aeration rate of 0.25 cu. ft. per gallon per hour, would require a total air supply of 1.8 cu. ft. per gallon of waste (Figure 6).

Effect of Waste Concentration

Previous experimentation on aeration of white water with nonfloceulent growths was conducted with white water that had not been concentrated. To determine the effect of concentration of the waste upon the rates and degrees of purification, and to determine the optimum concentration that could be efficiently treated by this method, white water concentrations of 500, 1,000, 2,000, and 3,000 p.p.m. B.O.D. were used.

The white water was concentrated to a B.O.D. of 6,000 p.p.m., diluted with distilled water to the B.O.D. concentrations used in the experiment, and air was supplied at a rate of 3 cu. ft. per gallon of waste treated per hour. The high air supply was used to insure sufficient air at the higher B.O.D. concentrations. The seed used had been acclimatized to white water for approximately 2 weeks and 20 per cent by volume seed added to the white water. Daily additions of white water were made, and 20 per cent of the settled supernatant was returned to the process for seed. Each waste concentration was run for 4 days prior to the determination of the purification rates. The experiments were conducted at 30° C.

Results show that purification of white water in concentrations of 500 and 1,000 p.p.m. proceeded rapidly during the first 12 hr., when B.O.D. reductions of 97 and 90 per cent, respectively, were reached. At a waste concentration of 2,000 p.p.m. B.O.D., a material decrease in the rate of purification occurred after 2 hr., whereas at a B.O.D. concentration of 3,000 p.p.m. the rate of purification was retarded after about 30 min.

The effect of waste concentration and aeration time upon B.O.D. reduction is

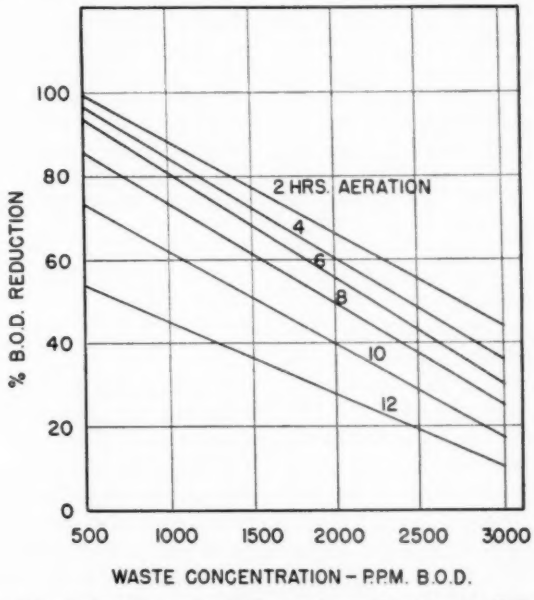

FIGURE 7.—Effect of waste concentration and aeration time on B.O.D. reduction.

shown in Figure 7. The B.O.D. reduction at any time is a linear function of the B.O.D. concentration of the waste within the limits of the waste concentrations used.

Results and calculations show that B.O.D. loads could be applied at the various waste concentrations to obtain a given degree of purification, but the optimum waste concentration appears to be approximately 1,000 p.p.m. At a B.O.D. concentration of 2,000 and 3,000 p.p.m., a slight decrease in loading resulted. With a waste concentration of 1,000 p.p.m., 80 per cent B.O.D. reduction can be effected with a B.O.D. load of 0.2 lb. per cubic foot of aeration capacity per day.

Discussion

Aeration of white water with nonfloceulent growths at a temperature in the thermophilic range results in approximately 65 per cent B.O.D. reduction in 2 hr. of aeration with a B.O.D. load of 0.30 lb. per cubic foot of effective capacity per day, but when B.O.D. reductions in excess of 80 per cent are required, aeration at 50° C. is not more effective than aeration within the mesophilic temperature range. A disadvantage of the aeration process at the thermophilic temperature is the increase in turbidity caused by the dispersion of bacterial cells in the liquid. This turbidity is not readily removed by settling, but can be removed by coagulation or by filtration with a small amount of filter aid. Filtration produces a sparkling effluent.

The initial high efficiency at the thermophilic temperature suggests the use of a two-stage system, the primary aerator operated at a temperature of 50° C. for 2 hr., followed by a mesophilic aerator. Approximately 65 per cent of the B.O.D. would be removed in the first stage and the turbidity could be removed with 1 hr. of aeration in the second stage. The second stage would remove additional B.O.D.

TABLE II.—Optimum Loadings at Various Temperatures

B.O.D. Red. (%)	B.O.D. Load (lb./1,000 cu. ft./day)			
	20° C.	30° C.	40° C.	50° C.
60	148	222	210	305
70	113	169	164	215
80	85	134	128	128

The optimum loadings vary with the temperature of aeration and the degree of purification required. In the mesophilic range temperatures of 30° to 35° C., about 80 per cent B.O.D. reduction was obtained in approximately 4.3 hr. of aeration with a loading of some 140 lb. B.O.D. per 1,000 cu. ft. aeration capacity. The optimum loadings at the various temperatures to attain various percentages of B.O.D. reduction are given in Table II.

The most efficient aeration rate appears to range between 0.25 and 0.5 cu. ft. of air per gallon per hour. At an aeration rate of 0.267 cu. ft. per hour per gallon, approximately 2.0 cu. ft. of air are required per gallon of waste to effect a B.O.D. reduction of 80 per cent, but maximum efficiencies vary also with the concentration of the waste. Greatest efficiencies were obtained with a waste having a B.O.D. concentration of 1,000 p.p.m. at a temperature of 30° C., and under these conditions the optimum loadings obtained were:

B.O.D. Red. (%)	B.O.D. Load (lb./1,000 cu. ft./day)
60	415
70	300
80	200
90	125

The loadings for 90 per cent B.O.D. reduction are substantially higher than those reported for a number of activated sludge plants. Greeley (2), in an analysis of activated sludge plants, found that with B.O.D. loadings of 40 lb. per 1,000 cu. ft. of aeration capacity per day, B.O.D. reductions of 90 per cent were effected. Loadings of 70 to

80 lb. per 1,000 cu. ft. aeration capacity have been obtained in several plants with nearly 90 per cent B.O.D. reduction, particularly when the sewage contained organic industrial wastes. Results of the aeration experiments on white water with nonflocculent growths show loadings and purifications ever higher than those obtained in the field and are comparable with activated sludge studies conducted under controlled conditions in the laboratory.

The loading on a cubic yard basis to obtain 90 per cent reduction of B.O.D. in the aeration of white water would be 3.4 lb., which is comparable to the loading on high-rate recirculating filters. Kehr and Ruchhoft (5) obtained 70 per cent reduction with a loading of 3.5 lb. of B.O.D. per cubic yard at the Neosho, Mo., sewage treatment plant. Greeley (1) reported a reduction of 57 per cent at 3.1 lb. of B.O.D. per cubic yard of filter media.

Heukelekian (3) reported that in the treatment of spent penicillin broth with nonflocculent growths, 77 per cent B.O.D. reduction was effected with an applied load of 130 lb. per 1,000 cu. ft. of effective capacity per day.

Sludge production from nonflocculent growth aeration is relatively low. The suspended solids in the aerator effluent ranged from 50 to 60 p.p.m., or about 460 lb. per million gallons of waste. The suspended solids settle readily, but do not compact to the same extent as settled sewage solids. The solids behave more like activated sludge floc, although compaction is better. Quiescent settling for 2 hr. produces a sludge concentration of about 2 per cent, and on this basis the volume of sludge produced would be approximately 370 cu. ft. per million gallons of waste treated.

The aeration process is efficient and can be readily controlled. The volume of seed used and the pH of the waste do not seem to be of critical importance. Seed can be readily developed by using sewage, soil suspensions, or river water, and an acclimatized seed can be developed in 3 to 4 days.

Conclusions

On the basis of the experimental results, calculations, and comparisons, the following general and specific conclusions have been drawn:

1. Aeration of white water and white water concentrate with nonflocculent growths is feasible in the thermophilic (50° C.) as well as the mesophilic range.

2. In the mesophilic range the optimum temperature is between 30° and 40° C., and at a B.O.D. loading of 200 lb. per 1,000 cu. ft. of aeration capacity per day, 80 per cent of the B.O.D. can be reduced in 4.3 hr. of aeration.

3. To effect a B.O.D. reduction of 80 per cent, approximately 2.0 cu. ft. of air are required per gallon of waste treated (B.O.D., 500 p.p.m.)

4. Waste concentrations up to a B.O.D. of 3,000 p.p.m. can be effectively handled by the aeration process. The process can be readily controlled, the volume of seed and the pH of the waste are not of critical importance, and a seed can readily be developed from sewage, soil suspensions, or river water.

5. Starting with sewage as a seed, an acclimatized seed can be developed in 3 to 4 days in the mesophilic range and in about 2 weeks in the thermophilic range.

6. A sludge volume of about 370 cu. ft. per million gallons of waste, having an initial B.O.D. of 500 p.p.m., can be expected.

7. A board mill of 100 tons daily production discharging 2,080 lb. of B.O.D. per day will require a minimum of 8,300 cu. ft. of aeration capacity to effect an 80 per cent B.O.D. reduction.

Summary

The system of nonflocculent growth aeration, effective for a number of strong soluble organic wastes, was studied for B.O.D. reduction of white

water. About 60 per cent of the B.O.D. of white water is exerted by the dissolved solids. Laboratory studies pertaining to the feasibility and factors affecting B.O.D. reduction of white water showed the method to be effective, efficient, and readily controlled. The most important factors are temperature, air supply, and B.O.D. concentrations. The volume of seed and the pH of the waste do not appear to be of critical importance. Temperatures in the mesophilic range (30° to 40° C.) are about as effective as temperatures in the thermophilic range in respect to the percentage B.O.D. reduction. Aeration time, waste concentration, and percentage B.O.D. reduction are related. At a temperature of 30° C. about 80 per cent of the applied B.O.D. can be removed with a B.O.D. load of about 200 lb. per 1,000 cu. ft. of aeration capacity per day.

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1953 MCA INDUSTRY CONFERENCE ON AIR POLLUTION

The 1953 Industry Conference on Air Pollution Abatement, sponsored by the Manufacturing Chemists' Association, will be held February 26–27 at the Hotel Statler, Detroit, Mich.

The meeting will feature papers and discussions on the technical aspects of air pollution abatement and on regional pollution control problems.

Stream Pollution

BIOLOGICAL EFFECTS OF POLLUTION IN MICHIGAN WATERS *

By Eugene W. Surber

U. S. Public Health Service, Chicago, Ill.

Quantitative studies of the bottom animal life of a river or lake can usually be relied upon to give a picture of the water quality that has prevailed in a given area over a period of several weeks or months. Some groups of aquatic insects, such as the midgeflies, have relatively short life cycles and can become abundant in an area, under favorable conditions, in a matter of a few weeks. Other groups, such as many species of mayflies and caddisflies, require several months, a year, or more to complete their life cycle. As an example, the large and conspicuous brown drake mayflies in the Mississippi River as nymphs burrow through the bottom mud in search of food for two years or more before they emerge in hordes on or about July 13, each year, when they molt, mate, lay eggs, and die, all within a few hours.

Sampling Methods

Many streams cannot be sampled in such a way that the samples will give a true picture of numbers of animals and kinds present all over the stream bed. For example, in the Mississippi River the kinds and numbers of animals that can live there are determined by sampling the mud-covered bottom with a Petersen or Ekman dredge in the more protected areas, which occur in the eddies behind wing dams and the quieter reaches away from strong currents. Samples can be collected with a Petersen dredge in mid-channel in unimpounded sections, but they usually contain nothing in the way of bottom animals because the bottom material usually consists of fine sand which is continually shifted.

In swift water, where there are gravel riffles and often large stones and flat rocks scattered about, the greatest variety and bulk of bottom animals occur because of higher oxygen and more food in the current, which brings food to certain kinds of animals more rapidly. Net spinning caddisfly larvae build silk nets on the surfaces of the stones, with which they trap microorganisms as they drift by in the water. Blackfly larvae have little basket-like structures on the sides of their heads, through which the water is strained for food. Large stonefly nymphs, many mayfly species, midgefly larvae, beetle larvae, snails, fingernail clams, and large dobsonfly larvae (hellgrammites) live upon, underneath, or among the rocks. To sample such a gravelly or rubble bottom, a certain stream bottom sampler is well-suited. This sampler is a square frame of brass, 12 by 12 in., with a net of about 23 to 30 meshes to the inch behind it. The gravel or rubble within the 1-sq. ft. area is turned over in the river water in front of the open net. Large stones with nets of caddisfly larvae, etc., attached are placed in a pail or small tub for removal of larvae later, but most of the animals within the 1-sq. ft. area detach

* Presented at 1952 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 19–21, 1952.

themselves from the stones as they are first turned or lifted and are carried by the current into the net.

Petersen dredge or Ekman dredge samples, from the quieter stretches where only mud is sampled, generally show fewer kinds of bottom animals because certain fast-water types such as hellgrammites, stonefly nymphs, and most species of caddisfly larvae are automatically eliminated, either because oxygen is not brought to their gills rapidly enough or because their methods of feeding are of a particular type.

In the quieter stretches debris deposited upon the bottom may make it physically impossible for animals to live there.

Effects of Sewage

Pollution may have the following modifying effects upon bottom fauna populations: Domestic sewage in quantities so dilute that oxygen levels through the day and night may be maintained continuously above about 5 p.p.m. may actually feed bottom animals and cause them to multiply indirectly by stimulating the multiplication of microscopic plants and animals upon which they feed, thereby increasing the food supply. The reason that some hardy species of fish such as carp and catfish are able to live in fairly highly-polluted areas is because they have rather specialized methods of propagation which enable their eggs to receive a higher degree of aeration than would occur if their eggs were deposited in gravel nests on the bottom in the manner characteristic of bass and other sunfish. Carp, for example, spawn on the submerged rootlets of trees growing on overhanging river banks or upon the leaves of aquatic plants, where their eggs are away from the decomposing organic material on the river bottom.

Ordinarily, sewage pollution reduces the number of species living in a given area to a few kinds which are specially adapted to living under low-oxygen conditions. The tubificids and red midgefly larvae, which combine the oxygen they can get with hemoglobin, are examples. Some animals, such as sewage flies (*Psychoda*), certain crane flies (such as *Tipula ignobilus*), and water boatmen exist in areas of heavy organic pollution because they can go to the surface where they can thrust a specialized air tube connected with their tracheal system through the surface film and get air directly from the atmosphere; or, in the case of water boatmen, they can carry an air bubble below the surface with them on specialized hairs or setae.

Effects of Toxic Wastes

Pollution by chemicals or toxic wastes is generally characterized by a general wiping out of certain species, particularly the sensitive mayfly and stonefly nymphs, caddisfly larvae, snails, and clams. Even the normally pollution-tolerant tubificid worms sometimes fail to survive contaminated waters receiving toxic material such as zinc, copper, phenols, etc. But sometimes there is merely a reduction in numbers of many forms, with the net result that the pounds of potential fish-food organisms per surface acre are reduced by a large percentage.

Illustrative Examples

The following examples of effects of both organic and chemical pollution upon Michigan streams are given to illustrate the foregoing matters.

In the discussion which follows, reference is made to clean-water, facultative, and pollutional animals. Probably, only the use of "facultative" requires explanation: facultative animals are those forms that are able to live in fairly heavily-polluted areas as well as in clean-water situations.

Menominee River System

The Menominee River and the Brule River form the boundary waters between Michigan and Wisconsin. The

Iron River is an important tributary of the Brule. The Menominee River proper begins at the junction of the Brule River with the Michigamme River. From this point to its mouth is a distance of 110.4 mi.

The principal pollution in the upper Menominee and Brule Rivers arises in the Iron River-Stambaugh-Caspian area (see Figure 1). Above the city of Iron River, the Iron River (tributary to the Brule) is a clear unpolluted trout stream. Iron River and Stambaugh, which is located about 7.6 mi. above the mouth of the Iron River, discharge their sewage untreated into the Iron River. However, the greatest damage to it is done by water pumped from the iron mines in the area. The iron mine waste water converts a clear stream into a red turbid stream. It is believed that the turbidity caused by the oxidation of iron prevents bottom animals from establishing themselves because of the in-

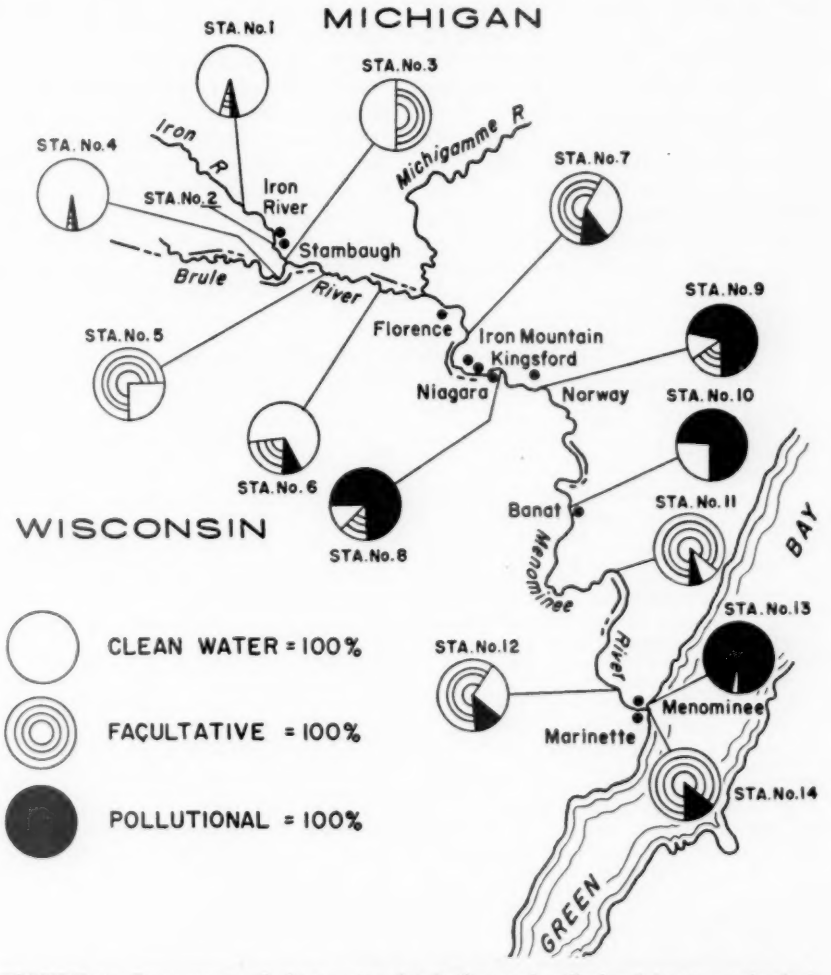


FIGURE 1.—Percentages of clean-water, facultative, and pollutional bottom animals in Menominee River, May, 1951.

ability of light to penetrate to the bottom.

On May 8, 1951, the riffles of the Iron River above Iron River, Stambaugh, and Caspian, Mich., supported at least 24 species of bottom animals. No animals were present immediately below these towns, and near the mouth of the Iron River only two kinds of bottom animals, both facultative forms, were present in very small numbers.

This section of the river showed a satisfactory dissolved oxygen content of 10.0 p.p.m. A relatively high B.O.D. of 10.2 p.p.m. and M.P.N. of 93,000 existed at Caspian on May 7, according to results obtained by the Michigan Water Resources Commission.

Iron River flows into the Brule River about 2.4 mi. below Caspian. The Brule River above the mouth of the Iron River is unpolluted and an excellent trout stream. Bottom samples were collected in the Brule River at Highway M-189 to obtain quantitative data on the abundance of bottom animals above the mouth of the polluted section of Iron River. The Brule River was found rich in bottom animals and supported nearly 5,000 bottom animals per square yard, including mostly clean-water animals belonging to the caddisfly and mayfly groups.

The pollution entering the Brule River from Iron River on May 8, 1951, was of sufficient quantity to seriously affect bottom animal life in the Brule River. At Pentoga, bottom animals were reduced to only 36 per square yard.

The next major source of pollution enters from the Iron River-Kingsford, Mich., area. At present, both Iron River and Kingsford discharge domestic sewage directly to the Menominee River untreated. The greatest single source of pollution in the upper reaches of the Menominee River has been the Kimberly-Clark pulp and paper mill at Niagara, Wis., employing the sulfite

TABLE I.—Sources of Pollution on the Menominee River

Approx. River Miles Above Mouth	Principal Sources of Pollution	1950 Pop.	Population Equivalent Discharged	Treatment
8.0	Iron River:			
	Iron River, Mich.	4,023	?	None
	Stambaugh, Mich.	1,969	?	None
	Caspian, Mich.	1,608	?	Imhoff tank
	Gaastra, Mich.	773[1]	?	Septic tanks[2]
	Several iron mines in Michigan			None
111.2[3]	Brule River:			
	Florence, Wis. (Fisher Creek)	1,353[4]	1,350	None
96.8	Menominee River:			
	Iron Mountain, Mich.	9,578	?	None
92.8	Kingsford, Mich.	4,982	?	None
	Iron Mines, Mich.	—	—	None
84.4	Niagara, Wis.	2,020	2,000	None
	Kimberly-Clark Paper Co.	—	235,000	Save-all
81.0	Norway, Mich.	3,275	?	None
1.8	Marinette, Wis.	14,198	8,750	Primary
	Marinette Paper Co.	—	92,300	Save-all
1.3	Menominee, Mich.	11,124	?	Intermediate
	Superior Sugar Co.[5]	—	92,300	Lagoons
	Marathon Paper Co.		?	?

[1] 1940 population.
[2] Two plants.
[3] Approximate river miles via Menominee and Brule from mouth of Menominee River.
[4] Township population.
[5] Seasonal.

process and discharging wastes with a population equivalent of approximately 235,000. Norway, Mich., also discharges about 750,000 g.p.d. of sewage and about 3,000 g.p.d. of clear mine water to the Menominee River through Sewer Creek. The pollution from Crystal Falls enters the Paint River, a tributary of the Menominee River, and apparently does not affect it seriously. Figure 1 shows the extent of recovery exhibited by the river between Niagara and the mouth of the river at Green Bay.

The Menominee River is apparently heavily polluted from the standpoint of biological effects near its mouth where the Marinette Paper Company, the cities of Menominee, Mich., and Marinette, Wis., the Marathon Paper Company, and the Superior Sugar Company discharge their wastes. The cities of Menominee and Marinette provide treatment plants. The industrial plants mentioned also have waste treatment facilities. The Marinette Paper Company hauls out approximately 50 per cent of its concentrated spent sulfite liquor for road and parking lot conditioning; the Superior Sugar Company, which operates seasonally, lagoons its wastes.

Table I lists the sources of pollution for the May 8–10, 1951, Menominee River survey. Figure 1 illustrates the percentages of clean-water, facultative, and pollutional animals, and the number per square yard found at each station.

Kalamazoo River

Another striking example of the effect of pollution is found on the Kalamazoo River.

The bottom fauna data for the Kalamazoo River for November 19 and 20, 1951 (Table II and Figure 2) illustrate more in detail how a well-balanced animal population above Battle Creek is destroyed and replaced by pollutional forms.

Above Battle Creek, 22 species of bottom animals, totaling 729 individuals per square yard, were found in a single square-foot stream bottom sample taken in a riffle area with gravel and rubble bottom. Mayflies, caddisflies, mollusks, beetles, aquatic earthworms, a variety of true flies, and true bugs (water boatmen) were represented.

Battle Creek discharges wastes, mostly domestic sewage, from a primary treatment plant. Biological conditions deteriorated rapidly below Battle Creek to the point where only three species of bottom animals were found at a point a short distance below the Fort Custer bridge. Of these, 100 per cent were classified as pollutional. The numbers of individual animals per square yard of bottom about 6 mi. below the source of pollution increased ten-fold, but nearly all of them were tubificid worms, which are able to live where there is very little oxygen and a great deal of organic pollution.

The damaging effects of Battle Creek sewage are reflected by the bacteriological data, which show an increase in most probable number (M.P.N.) from 4,600 to more than 140,000 per 100 ml., and an increase in B.O.D. from 4.6 to 5.2 p.p.m. during above average stream flows for this season.

At Galesburg, about 26 mi. below Battle Creek, the number of species of bottom animals was increased by one (to 4) and the number of individuals were fewer (603 per square yard), but again 92.7 per cent could be classified as pollutional.

At Comstock, about 30 mi. below Battle Creek, the stream has recovered to the degree that the wastes from Battle Creek serve as fertilizer, or indirectly as food, for the bottom animals. The number of species has increased over Galesburg four-fold (to 16); the fertilizing effects of Battle Creek sewage are reflected in a total population nearly eight times the population at the "control" station above Battle Creek. At this point, the coarse gravel in the

riffles was matted down with the self-spun nets of the caddisfly larvae *Macromena zebratum, Cheumatopsyche* sp., and *Hydropsyche orris*. The aquatic earthworms, fingernail clams, crayfish, mayflies, beetle larvae, and a few fly larvae were represented. Clean-water forms made up 93.6 per cent of the animals present.

Pollution from the City of Kalamazoo and its paper mills converts the river from a clear, recovered stream to gray, turbid, paper-fiber, and *Sphaerotilus*-laden water in which no fish can live. But the riffles, with some aeration, supported a very pollution-tolerant population of tubificids totaling 3,051 per square yard at Cooper Road, about 6 mi. downstream from Kalamazoo.

Below Plainwell Dam, only the very pollution-tolerant tubificids were to be found and these were very numerous. It is at this point that chemical and bacteriological samples showed deteriorating conditions prevailing on November 20, 1951, when the dissolved oxygen was 9.3 p.p.m. (an abnormally high value not characteristic of normal flows, when oxygen approaches 0.0 p.p.m.) compared with 15.0 p.p.m. above Battle Creek, the B.O.D. was 10.2 compared with 4.6 above Battle Creek, and the M.P.N. was 460,000 compared with 4,600 above Battle Creek.

At Otsego, about 20 mi. below Kalamazoo, there were relatively few tubificid worms, but a pollution-tolerant leech and a pollution-tolerant snail were abundant. Here the leeches were no doubt feeding upon the tubificids, thereby keeping their numbers down. Six species of bottom animals, 96.0 per cent pollutional, were found at this point.

Below Trowbridge Dam, tubificids numbered 26,685 per square yard. A total of six species of bottom animals

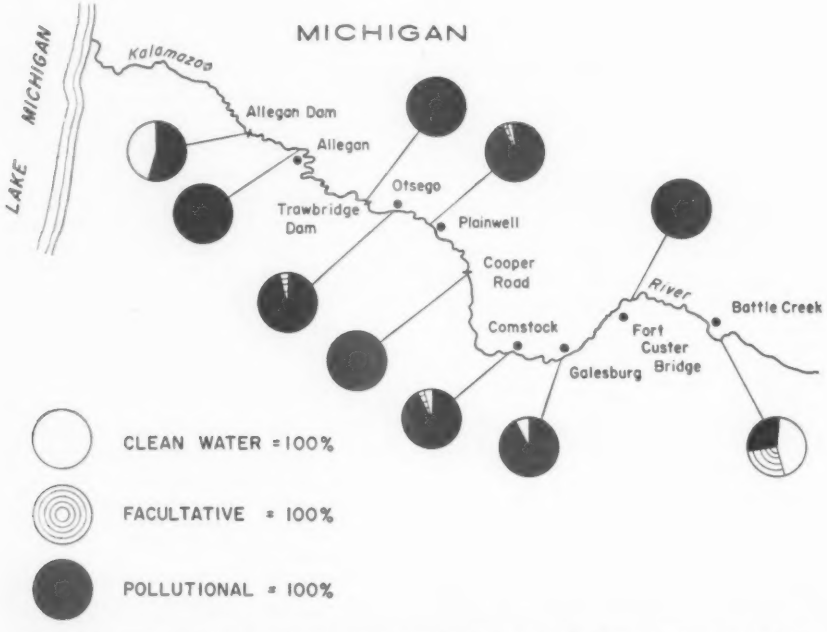


FIGURE 2.—Percentage of clean-water, facultative, and pollutional bottom animals in Kalamazoo River, Nov., 1951.

TABLE II.—Number of Bottom Animals Per Square Yard in Kalamazoo River, November 19–20, 1951

	Above Battle Creek	Fort Custer Bridge	Galesburg	Comstock	Cooper Road	Plainwell Dam	Otsego	Below Trowbridge Dam	Below Allegan Consumers Dam	Below Allegan Dam
Flatworms: *Euplanaria*	—	—	—	63	—	—	—	—	—	27
Roundworms: *Gordiaceae*	—	—	9	—	—	—	—	—	—	—
Earthworms: *Tubificidae*	54	7,713	558	18	3,051	630	—	26,685	819	81
Other	135	—	—	9	—	—	36	—	—	—
Crayfish, shrimp, etc.	—	—	9	72	—	—	—	—	—	54
Leeches	—	27	9	—	—	—	324	9	—	—
Snails and clams	72	—	—	225	—	—	522	180	—	—
Mayfly nymphs	117	—	—	18	—	—	—	—	—	—
Beetle larvae	63	—	—	2,394	—	—	—	—	—	—
Caddisfly larvae	153	—	—	2,520	—	18	—	—	—	—
Bugs (water boatmen)	18	—	—	—	—	9	—	—	—	—
Flies, larvae:										
Midgeflies	9	9	27	424	—	—	126	—	—	—
Craneflies	90	—	—	—	—	—	—	63	—	—
Blackflies	9	—	—	—	—	—	—	—	—	—
Other	9	—	—	54	—	18	—	—	9	—
Total no. of animals	729	7,749	612	5,797	3,051	675	1,008	26,937	828	162
Clean-water species	10	0	3	11	0	1	1	0	0	2
Facultative species	9	0	0	2	0	1	0	2	0	0
Pollutional species	3	4	3	3	2	3	5	4	2	2
Total species	22	4	6	16	2	5	6	6	2	4

was represented here also. All were pollutional forms. Below the Allegan Consumers Dam, about 35 mi. below Kalamazoo, only pollution-tolerant animals were to be found.

Recovery seems fairly rapid below the Allegan Dam, about 42 mi. below Kalamazoo. The presence of freshwater shrimp (*Gammarus*) indicated cleaner water than existed above the dam.

Lake Studies

Although the quantitative sampling of lakes is less difficult and can be carried out with greater sampling accuracy, the interpretation of results is more difficult, because the number of species present are often few.

In Michigan, however, it is believed that the results of bottom sampling in Fremont and Pickerel Lakes near Fremont, on January 29 and 30, and February 19 and 20, 1952, respectively, will serve as an illustration of the manner in which polluted and unpolluted lakes can be compared.

Fremont Lake receives the treated wastes of the city of Fremont, which has a large food processing plant with some special waste treatment problems. After this lake was sampled late in January, it was decided to sample Pickerel Lake, an unpolluted lake nearby with similar physical characteristics, to determine what differences existed in the bottom fauna populations of the two lakes.

In 13 samples from Pickerel Lake, the unpolluted lake, there was a total of 91,004 bottom animals for an average of 7,003 per square yard per sample. This could be compared with a total of 14,900 bottom animals in 23 samples from Fremont Lake for an average of 650 per square yard per sample. When the animals were classified as to their status as clean-water, facultative, or pollutional, and the possible pollution animals totaled, it was found that only 2.7 per cent of the animals could be classified as pollutional in Pickerel Lake, whereas 96.6 per cent could be classified as pollutional in Fremont Lake.

The midgefly larvae of *Chironomus tentans-plumosus* and *Procladius culiciformis* were responsible for the small pollutional representation in the unpolluted lake. These animals occur in natural deposits of rich mud containing algal cells and decaying vegetation. The most significant thing about the bottom fauna of Pickerel Lake as com-

pared with Fremont Lake, suspected of being excessively polluted, was the complete absence of tubificid worms. These animals are also characteristic of rich, partly decaying deposits of organic materials more often characteristic of polluted than unpolluted habitats. In Fremont Lake, about one-half (11) of the total number of samples contained them. At seven other stations in Fremont Lake, conditions were so poor, even in winter when in the deeper lakes oxygen conditions are at their best, that tubificids, phantom midge larvae, and all other animals could not live there.

Acknowledgment

The author is indebted to the Michigan Water Resources Commission for its splendid cooperation in carrying out the surveys reported herein and for supplying chemical and bacteriological data.

NPA RELAXES MATERIALS CONTROLS

Certain relaxations of construction regulations were recently announced by the National Production Authority, to take effect January 1, 1953. The action, originally scheduled for May 1, 1953, is said to represent the most significant easing of construction controls by NPA since the institution of the original construction order, M-4, on Oct. 26, 1950. The relaxations increase the amounts of steel and copper that may be self-authorized for commercial and most other types of construction. The ban on recreational, amusement, and entertainment construction also was lifted.

The relaxation, in the form of an amendment to Direction 8 to Revised CMP Regulation 6, discontinues the allotment U-6. Owners who are permitted to self-authorize purchase orders will use the allotment number T-9 for water wells and sewage systems and plants under the jurisdiction of the NPA Water Resources Division.

Beginning January 1, 1953, water and sewage projects will be able to self-authorize, per project, per quarter, controlled materials in the following amounts:

1. Carbon and alloy steel, 25 tons; including structural, but not to include more than 2½ tons of alloy and no stainless.
2. Copper, 5,000 lb.
3. Aluminum, 4,000 lb. (Relaxation on aluminum does not become effective until May 1, 1953.)

These quantities compare with previous self-authorized allowances of 5 tons of carbon steel (not to include more than 2 tons of structural, but no wide-flange beams or sections), 1,000 lb. of copper, and 2,000 lb. of aluminum.

In regard to the category "all other" construction, NPA is eliminating the distinction between "industrial" and "all other" construction and will permit the same self-certification quantities for both. Water and sewage projects will be included in the "all other" category.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

UP-TO-DATE JOB APPRAISALS

In view of the concern of wastes treatment administrators over the increasing difficulties of securing adequate numbers of competent employees, two articles in this issue of the JOURNAL deserve the careful study and appraisal of those at all employment levels. The first of these is "Job Analysis and Evaluation in the Classification of Jobs," by J. J. Wolf (see page 88). The second is the "Special Report on Sanitary Engineering Salaries," by Earnest Boyce and W. H. Wisely (see page 110). It is hardly possible to mention either of these subjects without involving the other to a greater or lesser degree.

As employees, all are interested in receiving adequate pay for services rendered. But the different pay levels for apparently similar jobs take more than superficial appraisal to determine. That is where the techniques of job analysis and evaluation must come into play, and where employee interest will probably be greatest.

Supervisory personnel, even to the level of the mechanic who has a single helper, will be particularly interested in the job classification procedures because, as Mr. Wolf puts it, they must (a) satisfy the desires of the man who does the work, (b) establish the qualifications required by those who seek to fill the job, and (c) establish adequate wage policies and levels in relation to the labor market from which they secure their personnel.

To deplore the inadequate wage and salary levels for personnel employed in the various phases of the sanitary engineering field is not enough; neither is the academic knowledge of how to proceed with job classification. The two must be combined to provide the urge to implement job classification, as it is only by gathering the required data and presenting them intelligently that much hope can be seen for many cases where inequalities in wage rates exist within a given plant. This, of course, is a matter that must be pursued at the local level, inasmuch as the several variables involved are almost entirely dependent on local conditions.

It seems paradoxical that as operators and supervisors we rely so heavily on the results of laboratory analysis of one type or another to keep our plants in good operating shape, but neglect to make more than a "wave-of-the-hand" analysis of the human element in plant operation. Certainly the personnel who operate and maintain the equipment should be chosen as carefully as the equipment itself—and then "maintained" in appropriate manner.

How better to set the "Specifications for the Selection and Maintenance of Operating Personnel" than by following through the three phases of job classification within your own plant organization?

H. P. O.

JOB ANALYSIS AND EVALUATION IN THE CLASSIFICATION OF JOBS*

By J. J. Wolf

Plant and Field Section Job Analyst, The Atlantic Refining Co., Philadelphia, Pa.

Each person's job is different from that of his neighbor. It is because of these differences that certain satisfactions are derived from jobs; satisfactions as to rates of pay, prestige, a sense of achievement, and others. One may also feel certain dissatisfactions, however, in that a neighbor or colleague, whose job seems no better than the one under appraisal, may earn a higher salary. A natural question is: what makes one job pay a higher salary than another? Since different jobs can command different salaries, some orderly method should be used in identifying and cataloging job differences.

Three Fundamental Phases

That is exactly what job classification does. Any system of job classification must satisfy both the men to whom it will be applied and the management who will apply and administer it. The workingman's interest in job classification comes from his desire to be paid the same as his neighbor for the same kind of work. Management's interest is based on its need to:

1. Satisfy the desires of the man who does the work.
2. Establish the qualifications required by the men who seek to fill the jobs.
3. Establish adequate wage policies and levels in relation to the labor market from which it secures its personnel.

There are a number of different plans or methods used in classifying jobs. They differ principally in the evaluation phase. Regardless of which plan is used, there are three fundamental phases. These are:

1. Job analysis.
2. Job evaluation.
3. Job pricing.

Job analysis seeks to determine:

1. What is being done, and how, and why.
2. The limits of responsibility placed on the men who work the job.
3. The surroundings and conditions under which the job is done.
4. The qualifications required of men who seek to fill the jobs.

In job evaluation the jobs are placed in the proper relative order of value one to the other.

Job pricing seeks to determine the general level of wages to be paid to previously evaluated jobs.

Job Analysis

All three phases of the classification system are necessary for a complete and well-rounded classification program. However, the first or job analysis phase can be carried out without doing job evaluation or job pricing. Job analysis, as part of a classification system, seeks to determine first what is being done, how it is done, and why it is done. For existing jobs this is done by an actual study and observation of the work being performed. In the case of new jobs to be created, the determination is not quite as easy. For these new jobs it is necessary for management to determine the nature of the operations to be performed, who will perform them and, as an indirect result, how many men will be required to staff the operations.

Job analysis seeks to determine, secondly, the responsibility limits of the

* Presented at 24th Annual Conference, Pennsylvania Sewage and Industrial Wastes Association; State College, Pa.; August 27–29, 1952.

job. This again is learned from a study of existing jobs or by setting up new jobs as indicated previously. Here is determined the kind of decisions the man is permitted to make himself and those he must refer to higher authority and the effect of these decisions on his own work and that of others. Also determined is the extent to which he is accountable for products made, equipment operated or maintained, methods used, etc., and the possibility and consequence of any error on his part.

As a third part of job analysis, the conditions are determined under which the work is performed. Is the workplace indoors or outdoors, clean or dirty? Are there conditions of temperature, pressure, fire, explosion, toxic or corrosive materials, or other hazards? What are the hours worked by the job-shift or day, or combinations of both?

Job Requirements

Thus far, the analysis has been based on facts gathered by study and observation. In the last step of job analysis, use is made of the facts previously gathered to make judgments as to the qualifications required to fill the job. In setting up these qualifications three major items are usually considered; namely, educational requirements, experience requirements, and physical requirements. Since one person's opinions as to job qualifications will differ from those of another, several qualified persons should participate in this phase of the analysis.

Educational requirements for the job will be based on that minimum level of educational attainment needed to perform the duties of the job. A laborer may be required to read, and perhaps to write and do simple addition and subtraction. On the other hand, a head operator may be required to use percentage and be able to read charts and graphs, or even have a knowledge of simple chemistry and physics. The determination of educational requirements is rarely as simple as this. Moreover, as jobs become increasingly complex, educational requirements usually become higher.

Experience requirements for the job are determined on the basis of the kind and amount of past experience necessary to start on the job, the new things which must be learned on the job, and how long it will take to learn them. Where there are a number of jobs in the plant the duties can be so arranged that a logical progression can be had from one job to another. A simple illustration might be a plant requiring a laborer, an operator helper, and an operator. The laborer's duties may be such that he covers a considerable portion of the plant sufficiently to become acquainted with the location of the various pieces of equipment. After a certain length of time he might qualify as an operator helper. However, before he could perform the duties of the helper he must learn something of the operation of the plant in order to be more than just another pair of hands to the operator. Therefore, there must be some indication, not only of the kind and amount of past experience required to start on the job, but also of those things which must be learned after a man is placed on the job, and how long it should take to learn them.

Physical qualifications are perhaps the easiest to fix upon. It is obvious that a laborer needs a strong back and good arms and legs. As jobs become less manual in nature these physical attributes become less significant. Consideration should also be given to special physical requirements. Some jobs require special finger dexterity. Some, such as a chemical tester or dye bath operator, require keen color perception. Others, such as an octane tester, require a high order of sound perception.

Job Evaluation

Having learned what is done, and how, and why, the conditions under which the job is performed, and the responsibility limits and qualifications for the job, we are now ready to enter

into the second phase, or the evaluation of the job. There are numerous evaluation plans in existence. However, there are three basic plans, which are used separately or in various combinations. The three basic plans are:

1. Job ranking.
2. Point rating.
3. Factor comparison.

Each has its advantages and disadvantages. Regardless of which plan is used, judgment plays a large part in its operation. As in the consideration of the job qualifications, job evaluation should be undertaken only through the participation of several qualified persons.

Job Ranking

In job ranking the job is considered as a whole and judgment is passed as to whether the job is more difficult or less difficult to perform than another. In considering difficulty, all of the elements mentioned previously—such as education, experience, responsibility—must be given attention. By considering each job and comparing it with every other job, a listing of jobs is finally arrived at in which the most difficult or biggest job is placed first in the list and the least difficult job is placed last. Job ranking has the advantage of simplicity and ease of application. However, it has the disadvantage that it does not place any scale or value on the job and, hence, does not indicate how much different one job is from another. It has the further disadvantage of not being applicable to more than a relatively small number of different jobs with any significantly satisfactory results.

Point Rating

Point rating systems break the job down into several component parts. These parts vary in number and scope, but include, in varying degrees, the complexity of the jobs; responsibility for materials, equipment, records, supervision, money, etc.; experience; education; hazards; strength; and others. Various levels of these components are arbitrarily defined and weighted and fixed-point scales are applied. The jobs are then examined as to where they fit on these fixed arbitrary scales and the total of the points so assigned for various components determines the value of the job.

Point rating systems have the advantage of clearly defined values for different levels of job components and are applicable principally to production line jobs that do not change significantly over long periods of time and in which significant differences can readily be recognized. By the very method in which the scales are set up, the system does not lend itself too readily to the operations in chemical plants or similar jobs. Its principal disadvantage lies in the rigidity of the scales developed and, in many cases, in the multiplicity of components so scaled. Point rating systems further require that a very detailed and minutely specific job analysis be made of the jobs.

Factor Comparison

A third evaluation method is factor comparison. While by no means perfect, it combines the better features of job ranking and point rating systems. Here again the job is broken down into its component parts, the number of parts or factors being dependent on how closely they can be differentiated without becoming unduly restrictive or creating overlapping areas. At least three factors are used; namely, complexity, responsibility, and conditions of the job.

In the evaluation plan used by The Atlantic Refining Company, use is made of factor comparison by the following five factors:

1. Mental effort.
2. Skill.
3. Physical effort.
4. Working conditions.
5. Responsibility.

For the factors of mental effort, skill, and physical effort, a genuine attempt is made to insure that the job content, the educational, experience, and physical qualifications required of the job, and the extent to which these qualifications are used in doing the job, are all examined. These factors are then compared with the same factors for similar or related jobs. The job under consideration is then placed in its proper scalar position relative to the jobs used for comparison purposes. In working conditions, the general surroundings and hazards of the job are examined and compared with the surroundings and hazards of similar or related jobs. In responsibility, the items for which the job incumbent is held accountable are examined, as well as the degree of the accountability and the possibility and consequences of any error on his part in carrying out his assigned responsibilities. Having thus scaled the job under consideration for the various factors, the total of these values represents the total of the job.

Regardless of which of the three systems of job ranking, point rating, or factor comparison have been used for evaluation purposes, one final step is necessary to complete the evaluation phase. This step is the grouping of the jobs into various labor grades, in order that there may be a sufficient degree of flexibility in the administration of the job rates and that narrow differences between jobs and a multiplicity of labor rates can be avoided. This grouping into job grades should follow a logical pattern consistent with the kind of analysis and evaluation procedure used, and should further provide for ready comparison with the labor market from which people will be drawn to fill the jobs.

Job Pricing

In the last major phase of the classification program, an effort is made to relate the jobs being classified with those in the labor market concerned. This is job pricing, and in this phase an attempt is made to determine the general level of wage rates in the labor market for the jobs required to be done. In carrying out the job pricing phase, there are three steps:

1. Conducting the wage survey.
2. Analysis of the survey data.
3. The determination, from the data, of the wage policy and levels for the jobs under consideration.

In conducting the survey, there are selected from among the jobs those which:

1. Are done by others in the general labor market.
2. All agree are properly related internally through the application of job analysis and job evaluation.
3. Have stable histories of wage levels and comparisons in the labor market.

The cooperation of competitors, allied, and related industries in the labor area is solicited to determine which of the jobs, as previously selected, they also have and what wage rates are paid for these jobs. These data are tabulated and analyzed by various means to determine the existence of any central tendency or band of rates.

If the central tendency is clearly shown, then this serves as a basis for indicating the wage scale to be applied to the jobs being analyzed. It is entirely possible, however, that no particular trend will be found. In that event, the data can serve only as a very broad basis to relate the company's total payroll to that of its competitors and related industries in the particular labor area.

Summary

In summary, jobs can be classified more easily and accurately by the application of a systematic and orderly program. The entire program entails job analysis, job evaluation, and job pricing. Job analysis determines the nature of the job and the qualifications

required by those seeking to fill the jobs. Job evaluation seeks to determine the proper internal relationship of job values within the company's own organization. Job pricing determines the proper external relationship between the company's jobs and those of its competitors and related industries in the particular labor market area. For a successful job classification program, job analysis is an orderly approach. Job evaluation and job pricing are essential for a complete job classification program.

OPERATION KINKS AT THE GOWANDA, N. Y., STATE HOSPITAL SEWAGE PLANT

By William L. Edwards

Senior Operator, Sewage Treatment Plant, Gowanda State Hospital, Gowanda, N. Y.

Much necessary repair work was recently completed at the Gowanda State Hospital sewage treatment plant.

Settling Tank Repairs

Evidently wear caused by extended use of the primary settling tank mechanisms caused the shafts to warp, breaking chains between the flights and even breaking the flights themselves. Why the shear pins did not snap remains a mystery. Both the No. 1 and No. 2 tanks were shut down within a month of each other.

It was necessary to melt the babbit from the bearings to get them off the shafts and ready to put on the new shafts. New turnshafts were installed in the bottom of each settling tank. The bearings were rebabbited 0.025 in. oversize. At the same time, the six sprockets on each skimmer unit also were restored to 0.025 in. oversize for freer operation.

The top shaft at the influent end of No. 2 settling tank was removed to install a new drive sprocket for the collector chains and flights. A new chain was put in from the drive sprocket to the reducing gear. New chains also were attached to the redwood flights in sections, the chains being stretched tightly over and around the sprockets by use of chain falls. This enabled removal of a few excess links from each side of the tanks. As part of the work, 8 new flights and 2 new pivoted flights were fastened to the chains in proper order.

All installations were checked in operation, the necessary corrections being made as to tank and sprocket clearance. The flights were cut to size wherever there was a chance of binding.

New pivot bolts and castle nuts with cotter pins were installed on each pusher flight. The saddles in which the peak cap sliding bearings were set had such a thin hairline of metal across the top that it was necessary to reinforce them with a solid piece of round steel bolted to a plate under the saddle. This proved satisfactory and saved the expense of buying new saddles, as well as eliminating a reoccurrence of the shaft damage. The T-rails were straight as originally installed and new T-rail wearing shoes were put on each new flight.

The rubber squeegees were then cut and attached to the skimmers and the skimmer chains were adjusted. Bearings were greased, and motors and reducing gears checked for oil and grease in preparation for a trial run.

The tanks were half-filled with water and the flights were run for one day before the tanks were refilled with sewage. Because the plant has no by-passes, it was necessary to keep one tank in operation while the other was out of service.

The rehabilitated tanks so far have been doing an A–1 job.

Digester Cleaning

During the summer of 1952 the No. 1 digester was emptied, as it was known that there was much heavy silt in the bottom. This also provided an opportunity to check the concrete work, hot-water coils, scum breakers, sludge stirrers, and gas domes.

Dewatering of the digester revealed a heavy concentration of sand and inorganic materials around the periphery of the tank away from the sludge stirrer paddles. This material had to be shoveled into buckets, hoisted out of the digester by ropes, and hauled away for disposal. Of the 80 cu. ft. thus handled, about 6 cu. ft. consisted of toothbrushes, combs, and pipe stems discarded by the patients. Mechanical installations and heating coils in the digester were found to be in excellent condition.

During the digester cleaning a suction blower was used to draw fresh air in through the scum manhole and out through the open gas dome. This worked well, no difficulty being experienced with gas at any time.

The gas dome and gas collector chamber were found to be in very bad condition. Therefore, they were cut out and new domes were fabricated and welded in. The steel work was then given two coats of Inertol paint before being put back in service.

Sludge Dewatering

In drawing sludge from the digester there had always been some difficulty encountered. With the enormous quantity to be dried during the digester dewatering operation, therefore, it was of advantage to experiment with procedures of conditioning and filtering.

In the present instance a total of 63,905 gal. was drawn, using 5,050 lb. of lime and 1,679 gal. of 15 to 20 per cent (Baumé) ferric chloride. The wet cake obtained amounted to 93.76 tons, or 30.81 tons of dry cake with a volatile content of 47.76 per cent.

Sludge from the digester has been of the thick, black, heavy type. When treated with ferric chloride in the first conditioning tank, it became so heavy

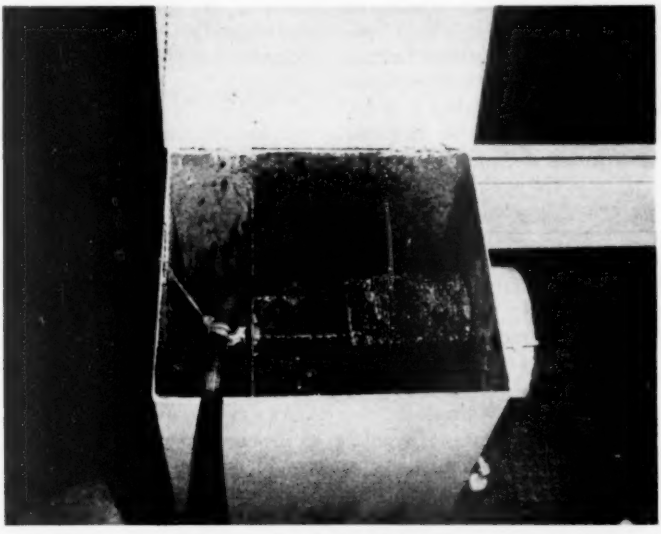


FIGURE 1.—Small stream of water into sludge inlet pipe to vat breaks scum film and keeps sludge running freely.

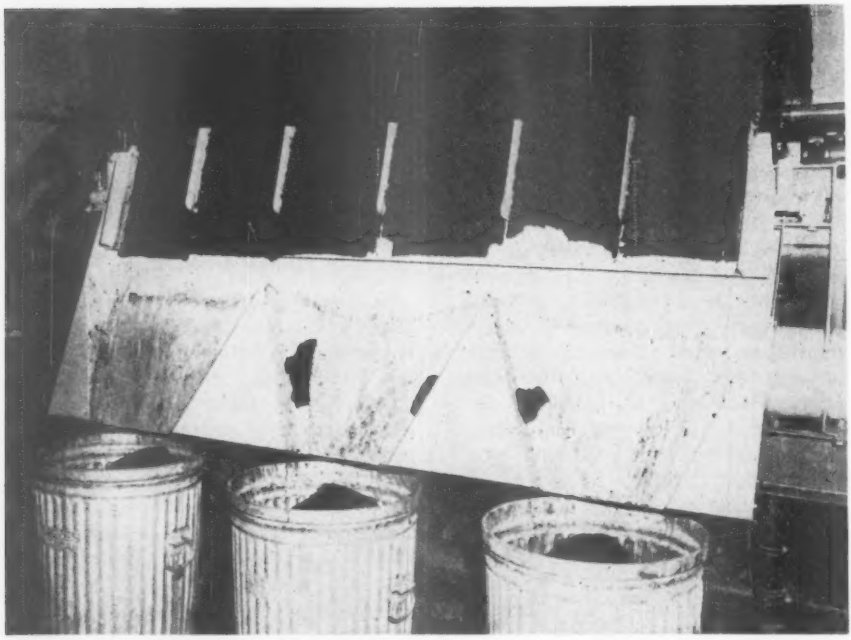


FIGURE 2.—Substitution of quicklime for hydrated lime in sludge conditioning eliminated cloth blinding during normal 6-hr. filter runs, increased filter effectiveness, and reduced operating costs.

and thick that water had to be added to keep it moving through the second to the third conditioning tank, where lime is introduced and the mixture is agitated by air. The mixture then flows to a bucket elevator for raising to a receiving chamber, from which it flows by gravity through a 3-in. pipe to the drum vat. The main problem has been to keep the heavy treated sludge flowing easily enough to maintain continuous operation of the vacuum filter.

Cloth blinding was only one phase of the problem, plugging of the system piping demanding much more attention. It took about 1½ hr., however, to wash and rinse the filter cloth, so production was extremely limited.

The first experiment was to add enough water in the initial conditioning stage to make the mixture flow easily. This, however, reduced the effectiveness of the ferric chloride. To restore the mixture to a proper drying time, more ferric chloride was added, which brought the quantity of this material considerably above that normally required for a given amount of sludge.

Further Conditioning Experiments

Other experimental changes included addition of just enough water in the first conditioning tank to maintain flow through the stages of ferric chloride and lime addition and mixing. At this time the correct amount of ferric chloride was added, but no excess of water. The sludge mixture then followed the original pattern of becoming too heavy and thick to flow from the elevator discharge to the sludge vat.

As a result, another change was made at the elevator discharge chamber (Figure 1), where enough water was added to thin the sludge mixture to a consistency suitable for maintaining a proper level in the filter tub. This procedure also kept the sludge mixture stable

enough so that the 16- to 20-sec. drying cycle could be held. Blinding of the cloth still occurred, however, after filter runs of 2 to 3 hr.

Apprehension about the rapid depletion of available chemical stocks led to further changes. Some drums of quicklime were obtained from the hospital waterworks, where it is used for pH control. Use of this form of lime in the same quantity as the hydrated lime, but with less ferric chloride, eliminated cloth blinding during normal 6-hr. filter runs. Using the quicklime and adding dilution water at the sludge elevator discharge chamber increased filter effectiveness (see Figure 2) to the point where a normal 6-hr. run dried from 3,700 to 4,165 gal. of sludge, producing from 100 to 125 cans of sludge cake weighing about 125 lb. each, or an average increase of 600 to 1,000 gal. and 35 to 50 cans, respectively.

Operational Economy

By introduction of a fine stream of water in the final stages of digested sludge conditioning and the use of quicklime with reduced ferric chloride dosage, the Gowanda State Hospital sewage treatment plant is saving hundreds of gallons of water, many pounds of chemicals, and 6 man-hours each day of filter operation, in addition to dewatering up to 1,000 g.p.d. more sludge containing more than half a ton of dry solids.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Experience is what you get when you're looking for something else.

20th and 21st Annual Reports of the Aurora, Ill., Sanitary District Sewage Treatment Plant for the Years 1950 and 1951 *

By Walter A. Sperry, *Superintendent*

General

The year 1950 broke 13 20-year weather records, which condition was reflected in plant operation. High flows with high dilutions necessitated giving only primary treatment to almost double the percentage of flow so treated in a 10-year period. The weather conditions also resulted in low total gas production (4,000,000 cu. ft. less than in 1949 and about 9,000,000 less than in 1948), necessitating excessive use of gasoline and fuel oil for engine operation and heating.

As a whole, 1951 was quite similar to 1950, both as to weather conditions and general quality of the raw and effluent sewage. Raw sewage flow averaged 8.1 m.g.d., up 11.3 per cent from 1950. Both B.O.D. and suspended solids were down, however, the former to 76 p.p.m. (111 p.p.m. in 1950), the latter to 162 p.p.m. (179 p.p.m. in 1950). Over-all removals were slightly lower in 1951 than in 1950, but gas production increased by 8.1 per cent.

Accidents

The plant accident record for 1950, although annoying as to number, was not serious. In May, a man fell off a ladder, suffering a strained back and requiring 4 days in hospital and 14 days off duty. Otherwise, there were 4 instances of foreign particles in the eye, requiring one doctor visit, but no lost time.

In 1951, four accidents necessitated compensation insurance claims. One of these was a minor eye injury. Another was an elbow injury, which did not in-

* For last previous extract see This Journal, **22**, 11, 1490 (Nov., 1950).

capacitate, but required several months of treatment. One man had a hand injured in handling heavy pipe out of the river. His recovery, however, was good. The final accident, occasioned by flooding of the plant garage floor one night during a heavy rain, resulted in a man slipping into a manhole, causing a nerve injury to the shoulder muscles which was so serious that recovery of the arm was questioned. This one accident alone will probably result in a fairly heavy compensation insurance claim.

TABLE I.—Summary of 1950 and 1951 Operation of the Aurora (Ill.) Sanitary District Sewage Treatment Plant

Item	Average 1950	1951
Rainfall (in.)	36.21	37.10
Tributary population (estimated)	57,250	58,500
Sewage treated (m.g.d.):		
Total	7.25	8.07
Complete	4.03	5.16
Primary only	3.22	2.91
Screenings (cu. ft. per m.g.)	1.08	0.75
Grit (cu. ft. per m.g.)	1.63	0.89
Volatile (%)	62.8	64.7
Grease and scum (cu. ft. per m.g.)	0.47	0.40
Suspended solids (p.p.m.):		
Raw	179	162
Settled	80	72
Filter effluent	60	48
Final	37	28
Reduction (%)	79.3	83.7
Pounds per capita in raw	0.189	0.186
B.O.D. (p.p.m.):		
Raw	111	76
Settled	76	60
Filter effluent	39	25
Final	28	18
Reduction (%)	74.7	78.0
Pounds per capita in raw	0.117	0.087
Oxygen consumed (p.p.m.):		
Raw	41	37
Settled	33	32
Filter effluent	29	26
Final	26	24
Reduction (%)	36.6	40.0
Nitrogen as free NH_3 (p.p.m.):		
Raw	8.1	6.6
Settled	8.4	6.7
Filter effluent	4.1	4.3
Final	4.9	6.0
Nitrogen as total org. N (p.p.m.):		
Raw	17.4	16.2
Settled	14.9	14.2
Filter effluent	11.2	11.0
Final	9.7	9.2
Nitrogen as NO_3—final eff. (p.p.m.)	4.9	6.0
Raw sludge:		
Total solids (%)	4.5	4.9
Volatile solids (%)	68.6	68.5
Equiv. dry sol. pumped (lb./day)	280	220
Final settling tank sludge:*		
Total solids (%)	4.4	5.1
Volatile solids (%)	56.4	57.2
Equiv. dry sol. pumped (lb./day)	27	41

*To 2nd-stage digesters.

TABLE I.—*Continued*

Item	Average 1950	1951
Transfer sludge—1st stage to 2nd stage:		
Total solids (%)	1.8	2.2
Volatile solids (%)	52.2	51.5
Equiv. dry sol. pumped (lb./day)	113	100
Digested sludge:		
Total solids (%)	9.5	9.3
Volatile solids (%)	53.8	48.4
Supernatant (from 2nd-stage digesters):		
Total solids (%)	0.26	0.42
Volatile solids(%)	47.8	49.7
Gas production:		
Cu. ft./lb. volatile matter added	4.94	5.29
Cu. ft./lb. volatile matter destroyed	14.70	10.4
Cu. ft./m.g. sewage	4,140	4,010
Cu. ft. per capita	0.524	0.553
Gas produced in 1st stage (%)	64.2	73.6
Gas composition:		
CO_2 (% Vol.)	31.9	32.5
O_2 (% Vol.)	0.3	0.3
H_2 (% Vol.)	3.1	2.4
CH_4 (% Vol.)	63.5	63.9
N_2	1.0	0.8
H_2S (p.p.m.)	118	132
B.t.u. (net)	581	584
Gas engine earning statement:		
Total engine investment ($)	18,321.50	18,321.50
Net earnings in year ($)	1,006.86	1,772.64
Total net earnings to date ($)	69,146.35	70,918.99
Plant operating costs ($):		
Payroll	36,909.84	41,008.04
Retirement fund	3,898.84	3,997.50
Interceptor system	2,824.37	2,865.61
Truck	138.18	192.87
Office	646.42	723.60
Laboratory	241.43	330.19
New equipment	5,209.90	608.08
Repairs	2,738.23	3,015.29
Gas engines	4,487.38	3,994.69
Miscellaneous	4,455.95	3,661.93
Total	61,550.51	60,397.80
Total cost per m.g.	23.25	20.50
Total cost per capita	1.075	1.033
Total disbursements (operation, interest, bonds, etc.) ($):		
Per m.g.	67.78	31.73
Per capita	3.14	1.60

Improvements and Additions

The tractor with "saddle" bins, used for sludge bed work, was replaced in 1950 by a new tractor with new bins of the same general design, but greatly improved in the matter of using a heavier weight of rust-resisting steel and in the provision of a winch arrangement for quickly removing the bins for maintenance purposes.

During the same year the muffler in the pump room engine system was eliminated and a new design of heat exchanger was installed. It is anticipated that the new unit will be more efficient as a heat exchange device and will give less trouble from corrosion.

The year also saw all of the stucco removed from the screen house, and treatment of this building with a two-coat application of gunited waterproofed concrete. Not only was the appearance of the building much improved, but the maintenance treatment

also bids fair to last for 10 or more years. The digester building was single-coated with the same material.

The lighting system in the office, laboratory, and shop was changed from incandescent to fluorescent type, greatly improving the lighting conditions in these rooms.

New aluminum deck plates were added to the catwalk located in the sludge valve pit between the clarifiers. The iron webbing formerly used had completely rusted away.

Building improvements in 1951 consisted of new roof coatings on the clarifier house and gunite coating of the clarifier house walls. The office and laboratory floors were relaid with Linotile blocks, replacing the worn-out battleship linoleum. A new overhead lighting system was installed in the pump room to remedy the poor conditions existing.

Maintenance

Besides the usual maintenance work, there was the unusual necessity for replacing more than 50 filter nozzle heads that had been kicked off by a group of boys visiting the plant on a Sunday. The damage was repaired by silver soldering the head to the stem for about $30, whereas replacements would have cost about $130.

A slight difference in the spacing of the flight chain sprockets on one of the three shafts in the secondary settling tanks had worn more than 100 link pins almost to the breaking point. The repair consisted of using hydraulic jacks

TABLE II.—Summary of 1949–50 and 1950–51 Operation Data at Detroit, Mich.

Item	Average 1949–50	1950–51
Rainfall, total (in.)	43.15	34.47
Sewage temp. (°F.)	65	65
Est. connected pop.	2,550,000	2,600,000
Sewage pumped (m.g.d.)	402.1	387.6
Solids removed:		
Grit, total (tons):		
Wet	17,721	17,177
Dry	8,566	7,704
Volatile	3,064	3,163
Sluiced wet	345	819
Tank scum, total (tons):		
Wet	1,607	1,717
Dry	1,045	1,117
Volatile	940	1,007
Susp. solids, total (tons):		
Dry	61,209	60,768
Volatile	38,586	40,083
Total solids, total (tons):		
Dry	70,820	69,589
Volatile	42,590	44,253
Analytical data:		
Susp. solids (p.p.m.):		
Influent	210	217
Effluent	111	115
Reduction (%)	46.9	46.7
B.O.D. (p.p.m.):		
Influent	143.4	125.1
Effluent	87	73.5
Reduction (%)	39.3	41.3
Grit:		
Solids (%)	48.3	45.4
Volatile (%)	35.8	41.1
Raw sludge to digester:		
Total solids (%)	10.4	10.2
Vol. solids (%)	57.7	58.3

TABLE II.—*Continued*

Item	Average 1949–50	1950–51
Sludge digestion:		
Total added (m.g.)	25.45	30.06
Dry solids added (tons)	11,254	13,331
Dry solids withdrawn (tons)	7,121	10,676
Gas produced:		
1,000 cu. ft.	82,560	87,533
Cu. ft. per lb. vol. sol. added	6.29	5.64
Cu. ft. per lb. vol. sol. cons.	14.04	20.97
Supernatant:		
Solids (%)	6.2	8.0
Vol. solids (%)	47.4	50.6
Sludge filtered:		
Mixed sludge to filters:		
Solids (%)	10.3	10.4
Vol. solids (%)	57.1	57.8
Total (m.g.)	103.48	107.98
Dry solids (tons)	47,154	48,626
CaO used (%)*	9.4	9.4
CaO used (%)†	12.8	12.0
$FeCl_3$ used (%)	1.02	0.62
$FeSO_4$ used (%)	3.75	2.04
Filter yield (lb./sq. ft./hr.)	3.2–5.1‡	3.5–4.4‡
Sludge cake:		
Total solids (%)	35.5	34.9
Vol. solids (%)	52.1	53.8
Incineration:		
Wet (tons)	173,675	179,446
Dry (tons)	64,375	64,813
Volatile (tons)	32,497	34,302
Wet feed rate (tons/hr./incin.)	10.0	9.8
Fuel oil per wet ton burned (gal.)	0.084	0.056

* With $FeCl_3$. † With $FeSO_4$. ‡ Depending on conditioning chemicals used.

to slide the misplaced sprocket back to its correct position and replacing the worn pins.

Severe corrosion of the gas supply line leading from the digester house to the secondary pump house was found by introducing a pint of synthetic wintergreen oil into the pipe. By driving rods into the ground along the route of the pipe, located with magnetic apparatus by the local gas utility, the odor of wintergreen oil quickly revealed the punctured condition of the pipe. The obstructed routing of the line would have made replacement extremely uneconomical, so permanent arrangements for an oil heater and fuel oil storage tank were made.

Table I is a summary of the 1950 and 1951 operating data.

Annual Reports of the Detroit, Mich., Sewage Treatment Plant for the Fiscal Years Ending June 30, 1950, and June 30, 1951 *

By Fred H. Burley, *Engineer of Sewage Treatment*

Sludge Conditioning

Sludge solids filtered during the year (1949–50) totaled 47,154 tons: 34,301 tons using ferric chloride as the coagulant, 10,393 tons with ferrous sulfate, and 2,460 tons with a combination of the two.

Use of ferrous sulfate in the form of

* For last previous extract see This Journal, **22**, 7, 944 (July, 1950).

waste pickle liquor from a nearby steel mill began on a routine basis in October. One additional 10,000-gal. storage tank, new pumps, and new piping were installed during August and September. The new storage tank and piping are equally suited for ferric chloride.

Normal operation contemplates 60 per cent use of ferrous sulfate and 40 per cent use of ferric chloride during all seasons of the year when sludge is amenable to the former. This permits a close comparison of results for each coagulant under similar operating conditions and a dual source of supply.

Waste lime slurry from acetylene manufacture continues to be the major source of lime for sludge conditioning. A stand-by is kept on hand in the form of pebble lime.

Chemical dosages have been successively reduced until, in 1950–51, the following dosages were used:

Ferric chloride	0.62 per cent
Ferrous sulfate	2.04 per cent
CaO, with $FeCl_3$	9.4 per cent
CaO, with $Fe(SO_4)$	12.0 per cent

An experimental run was conducted using chlorinated pickling liquor with lime as conditioning agents. In this run 1,363 tons of dry solids were filtered with 12 tons of chlorinated pickling liquor as a ferric chloride equivalent. This required a 0.90 per cent dosage.

Miscellaneous

A compressed air line was installed between the pumping station and the sedimentation tanks during 1949–50. This provides air to clear out plugged sludge lines, break down arched sludge blankets, and operate pneumatic equipment. Also, a steam line was installed in the railroad track scale pit to prevent excessive rusting of the scale beams and knife edges.

Operating data for 1949–50 and 1950–51 are summarized in Table II.

FLUSH TANK USED TO PREVENT SEWER FREEZING

By Edwin M. Lamphere

Assistant Sanitary Engineer (R), *Arctic Health Research Center, U. S. Public Health Service, Anchorage, Alaska*

In Fairbanks, Alaska, the problem of freezing sewers has plagued residents and city officials ever since the present sewer system was constructed in 1938. In the approximately 13 mi. of sewer lines, there are more than 100 dead ends. There is as little as 4 ft. of cover over the lines in many places; and since they are laid in the street, the insulation value of snow cover is practically eliminated. The water supply of Fairbanks consists of private wells giving water of poor quality (hardness up to 900 p.p.m. and iron up to 100 p.p.m.). This results in low water usage. These facts, together with relatively flat grades and an extreme climate, lead inevitably to freezing.

When freezing occurs, the lines must be thawed with steam generated by portable boilers. The annual cost of such thawing operations alone is approximately $20,000, an exorbitant cost for a city of 8,000 population. Various devices and operating procedures have been carried out in an attempt to overcome this annual costly freeze-up. One such device is described in the following.

Observations on the system beginning in 1949 indicated that low flow was one of the most significant factors affecting freezing. Accordingly, in October, 1951, the city of Fairbanks, in cooperation with the Arctic Health Re-Research Center (U.S.P.H.S.), con-

structed a flush tank at one of the dead ends to determine whether or not freezing could be prevented by its use. A line that had $1,500 in thawing costs charged against it for the previous winter was selected for the test.

Tentative plans followed conventional flush tank design with the exception that the water was to be heated. Both oil and electricity were considered as means of heating. Oil heat was ruled out because it would require more attention than could be given it. Investigation of power costs showed electricity to be too expensive. Therefore, the heating idea was dropped.

As-Built Construction of Tank

Since winter was just around the corner, the final design was dictated by whatever materials and equipment could be obtained within a reasonably short length of time.

The as-built construction of the tank is described as follows:

A section of 4-ft. wood stave manhole with a mastic-coated, 2-in. plank bottom and a 2-in. plank cover was used for the tank proper. In addition to being cheaper, the manhole section was much easier to install in freezing weather than either masonry or concrete.

To control flushing, a 4-in. Miller siphon with a drawdown depth of 13½ in. was used. This arrangement discharges about 115 gal. per flush.

A 2-in. well was driven through the bottom of the tank to supply the necessary water. A pump with a capacity of 660 g.p.h. was available, so that is what was used. The pump was mounted inside the tank, as close to the top as possible.

As a precaution against flooding the pump motor if the sewer froze in spite of the flush tank, a check valve was placed in the tank outlet and a float switch was attached to the motor.

To allow easy access to the tank no backfill was placed over the top. In its place, a 4-in. layer of sawdust enclosed in a canvas sack was used.

Thermocouples were placed outside the tank at 1-ft. intervals from the top of the tank to 1 ft. below the tank bottom. These were installed to determine whether or not some type of insulation might be valuable in future installations of a similar nature. Thermocouples were also placed in the water supply line, in the water in the tank, and in the air above the water level.

Operation

The tank was put into operation on December 12, 1951. Leakage was noted on this date to be about 250 g.p.h. through the tank. However, by the middle of February, 1952, leakage was practically non-existent and development of the well had raised the pump output from 400 g.p.h. to 825 g.p.h.

When operation was started, a 200-w. light bulb was placed inside the tank above the water level to prevent icing and to keep the pump warm. Bulbs of successively smaller sizes were installed as time went on, and eventually thermocouple readings showed that a 25-w. bulb would supply plenty of heat with outside air temperatures down to −50° F.

The sewer was kept open during the entire winter by use of this tank, although a power failure in January nearly spoiled the record. As a result of the power failure, the pump was stopped for four days and at the end of this time inspection at a downstream manhole showed the line to be about three-fourths full of ice. However, a few flushes cleared away the ice and no further trouble was experienced.

Costs

Construction costs of the tank came to $852.00 and the power bill for the four months of operation was $87.00. Thus, when this total is compared with the $1,500 thawing costs of the previous year the flush tank not only paid for itself, but saved the city approximately $560.00 in the first year.

On the basis of the past winter's experience with the flush tank, the city of Fairbanks plans to install at least one and possibly more tanks during the summer of 1952. Construction costs on these tanks should be much less than on the 1951 tank as the ground will not be frozen when they are installed.

TIPS AND QUIPS

Plant Operation Manual

A manual of operation for the specfic plant can be a great help to operation personnel, particularly if they are new to the field and in the processes of learning. With this in mind, Irvin Knoebel, superintendent of the Belleville, Ill., sewage treatment plant prepared an operation manual tailored to the equipment and processes of his own plant. Not only does this relieve him of answering so many stock questions of new personnel, but it also tells his workers what takes place, and why, and where things are.

Oddly enough, to be able to explain the details to someone else in the cold language of type is a good test of one's own knowledge of the matter. Try it some time!

Wire and Filter Cloth

A 126-page catalog that is in reality a textbook of the wire cloth, filter cloth, and fabricated products industry has recently been published. Included in the book are specifications, characteristics, and uses of wire cloth and filter cloth, as well as a report on 18 months of research into the flow characteristics and particle retentivity of metallic filter cloths conducted at Columbia University, and many pages of valuable engineering data.

The publisher is Multi-Metal Wire Cloth Co., Inc., 1350 Garrison Ave., New York 59, N. Y.

Do's and Don'ts for Pipe Valves

1. Clean all valves before installation, and install carefully, according to directions.

2. Cut pipe threads the proper length. Too long threads permit the pipe to run up against the seat diaphragm and ruin the seat.

3. Put pipe compound on the pipe, not in the valve where it will gum up working parts.

4. Use a proper-size or properly adjusted wrench on the valve end being screwed on. Otherwise the valve will be distorted, strained, or scarred.

5. Keep the valve closed during installation. This keeps it rigid and avoids entry of dirt.

6. Support long pipe runs properly. Sag may spring the valve seat and cause leakage.

7. Normally, install globe and angle valves with pressure under the disk, unless the valve is to be open in case of breakage or for other special reasons.

8. Tighten bolts or flanges on bonnets uniformly.

9. Blow or flush valves after installation to remove foreign substances.

10. Don't use bars or wrenches to operate valves. The handwheel gives all necessary leverage if valves are operating properly.

11. If the valve seats improperly, reseat it—don't force it.

12. Open valves on pressure lines slowly—quick opening causes water hammer (on steam lines from condensation) and strains lines and fittings.

13. As soon as a valve begins to leak, reseat, regrind, or rewasher it. Otherwise it may be worn beyond repair. Inspect all valves regularly.

Acid Carboy Dumper

A new carboy dumper, for use with hoists or overhead conveyors, is claimed

to permit safe, quick handling of acids. An important feature is that the dumper permits the carboy to be tilted to any angle and locked in position to assure steady pouring. Chains at the bottom and top keep wood from splitting or pulling out during handling. Details are available from General Scientific Co., 27th and Huntingdon Streets, Philadelphia 22, Pa.

Imhoff Scum Breaker

According to a recent issue of *Sanitary Engineering News*, monthly newscast of the Purdue University Sanitary Engineering Department, some ingenious person at Gordon, Nebr., has utilized some spare vertical motors, and augers from tractor-powered posthole diggers to break up the scum in the city's Imhoff tanks. Maybe this could be a new use for old postholes!

Electronic Deodorizer

A new gadget for deodorizing such persistent odors as onions, cabbage, fish (both cooking and long dead), and cigar smoke, has made its appearance on the market. Called the "Rid-All Double Bulb Electronic Deodorizer," the unit is actually smaller than its name would imply.

According to the distributor, Abbeon Supply Co., 179–15 Jamaica Ave., Jamaica, N. Y., the plug-in unit changes the oxygen of the air to ozone, which destroys any odor completely. A single unit is said to deodorize spaces up to 1,800 cu. ft.

What really is needed is a king-size unit of this type for use in screen houses or around trickling filters. Or even, perhaps, continuous units to trap wayward aromas from entire sewage treatment plants!

Amen!

Under the heading "In Defense of Sewers," *Engineering News-Record* (Nov. 27, 1952; page 96) recently carried the following editorial:

"An account of recent developments in fluorescent lighting in our issue of October 30, ended with the following cryptic statement: 'Finally, there is available a new disposal unit for used fluorescent tubes that sells for less than $90. It crushes the lamp into a powder which can be washed down a drain.'

"Sanitary engineers and city public-works officials might well have wondered at that statement: What next is to be flushed down the drain?

"We recently reported a prediction that by 1975 some 65 to 75 per cent of all garbage will be ground and put into the sewers. That is all well and good if cities plan for it and design new disposal facilities to handle the added load.

"But a line should be drawn somewhere. Today fluorescent tubes, burned out by the hundreds in large cities, are proposed for drain disposal. Tomorrow it may be paper, tin cans or ashes. It would seem to us that the makers of fluorescent tube grinding units might furnish cartons marked 'Poisonous' in which the ground glass with its toxic coating could be placed for disposal as dry refuse in safe areas on dumps. Even sewers can be abused."

This so well expressed the basic thinking of most persons concerned with sewer design and maintenance, and sewage treatment, that we can only add our hearty "Amen!"

Safety Note

Safety means always thinking ahead far enough to do the job with proper tools, at the proper time, in the proper manner. It is possible for a person to be entirely safe by doing nothing. But real safety is aimed at getting the job done properly and without injury. What good are results if you're not around to enjoy them?

Federation Affairs

SILVER ANNIVERSARY MEETING REPORT

The gala 25th Annual Meeting of the Federation, held at the Hotel Statler in New York City on October 6–9, 1952, provided a fitting celebration of the close of the first quarter century of Federation growth and achievement. New records were set in all registration categories. Of the 1,152 persons registered for the meeting, 943 were men and 209 were ladies. The previous high total and men's attendance had been established at the Washington, D. C., meeting in 1950 with 904 and 753, respectively. The previous high for ladies' attendance had been established at the Toronto meeting in 1946 with a mark of 202.

Particularly noteworthy was the excellent representation of those attending the meeting, from the viewpoints of both geographical and employment distribution. This same diversity of interest was reflected in the program as presented.

For the outstanding success of the meeting, great credit is due the host New York Sewage and Industrial Wastes Association, the Convention Management Committee, and the Local Arrangements Committee, headed by George E. Symons. The smoothness and precision of the various presentations at the meeting stemmed from the earnest and painstaking attention to details by the various local committees comprising the last group.

The Silver Anniversary Meeting was convened at 10:30 A.M. on Monday, October 6, 1952, by President Earnest Boyce, who welcomed the members and guests and commented briefly on the 1951–52 activities of the Federation. The business portion of the opening session was concluded with the Executive Secretary-Editor's report by W. H. Wisely.

Technical Program

The technical program, developed by the Program Committee under the chairmanship of F. W. Gilcreas, also reflected admirably the progress made in coverage and interests by the Federation during the first 25 years of its development. In addition to several papers on topics of broad interest to all Federation members, there were many papers on specific pollution and waste treatment problems.

For the first time, the Industrial Wastes Forum occupied a separate session of the program. This extremely popular feature of the past few Federation meetings was well attended and received. As always, the Operators' Forum also drew a good attendance. The lively discussions from the floor in both these sessions were indicative of the great interest in the several topics chosen.

The technical program presented at New York was as announced in the "Silver Anniversary Meeting Preview" (THIS JOURNAL, **24**, 9, 1192; Sept., 1952). Technical program papers are to be published in 1953 issues of the JOURNAL, beginning in February.

Entertainment Events

A "Family Night Entertainment" on Monday evening, October 8, featured an excellent variety show by professional talent and the Hyatt Glee Club. The latter organization is made up of male employees of the two Northern New Jersey plants of the Hyatt Bear-

ings Division, General Motors Corporation.

The Silver Anniversary Luncheon, held in the Penn Top of the Hotel Statler on Tuesday noon, was attended by about 400 persons. Highlights of this event included introduction of those members of the original Board of Control who were present and introduction of Quarter Century Operators' Club members. The featured speakers were Charles A. Emerson and Abel Wolman, original chairman and vice-chairman, respectively, of the Federation. Mr. Emerson reviewed the interesting developments in the Federation's activities during the early years; Dr. Wolman emphasized the responsibilities and problems confronting the Federation in the future. Both of these thought-provoking addresses are to be published in the February issue of the JOURNAL.

To close the Luncheon program, Toastmaster W. J. ("Bill") Orchard summed up the remarks with the following:

A Toast to the Federation

I'm honored more than I can say
To be presiding here today
To celebrate with cheer and glee
Our Silver Anniversary.

George Fuller was the author
Wrote the script—and set the scene.
Charles Emerson got it rolling
Toward fields of proven green.
For thirteen years he led us,
And served us hard and well,
Then passed the ball in forty one
To Arthur S. Bedell.

George Schroepfer and big A. M. Rawn
Continued pushing on and on.
Bert Berry and John Hoskins too,
Frank Friel and good George Russell,
Kept pressure coming from the top
To make committees hustle.
Vic Ehlers and then A. H. Niles
Put fine new records in our files.
Ralph Fuhrman and then Earnest Boyce
Affirmed the wisdom of our choice.
And next will come E. Sherman Chase,
A-sitting proudly in first place.

Those are the leaders—fine men all—
And helped by many, many more
They kept this Federation ship
Headed toward that shore
Where sewage works and trade waste plants
Will always be impeccable;
And those who guide and nurture them
Considered most respectable.

So stand up now—each one of you—
And hold your glass on high.
Forget about the byegone days,
Forego nostalgia's sigh.
And now I offer you a toast
To a future fine and grand,
And a Federation glorious
That grows to beat the band—
Making trade wastes into whiskey
With a rare exotic smell,
And refining domestic sewage
So it doesn't smell like Hell!

The Annual Federation Dinner and Dance, held in the spacious Main Ballroom of the Hotel Statler on Wednesday evening, October 8, was attended by 625 members and guests. At the Dinner, which was the climax of the meeting's social program, President Boyce presented the annual Federation awards and introduced the new officers. Dancing followed, to round out a most enjoyable evening.

Ladies' Entertainment

The entertainment features planned for the ladies by the local Ladies' Entertainment Committee, under the chairmanship of Mrs. Karl Mann, were extremely well received by the record-breaking group of ladies attending the meeting. Particularly noteworthy was the gracious hospitality and the friendliness with which the visitors were received by committee members.

The Monday tour of the United Nations Buildings, repeated on Wednesday for those who preferred that time, gave an opportunity to see at first hand the facilities and organization of the world-wide body.

The fashion show and tea on Monday afternoon gave an opportunity to meet and get acquainted, while seeing the latest in fashions and accessories. This

function, held at the B. Altman and Co. store, was generously and graciously financed and sponsored by the host New York Sewage and Industrial Wastes Association.

On Tuesday afternoon the ladies took a sight-seeing boat trip around Manhattan. This proved an especially delightful way to view the major sights of the area, including several of the largest ocean liners in port, the famous bridges, the Statue of Liberty, the New York water front and harbor, the New York sky line, the Hudson River Palisades, and many other attractions.

Many visitors enjoyed the several opportunities provided to attend radio and television broadcasts and to see some of the then current Broadway plays. Wednesday was left open for optional sightseeing tours or for shopping, according to the individual's desires. The day's activities concluded with return to the hotel for the Federation Dinner and Dance. Thursday also was open for shopping.

Men's Inspection Trip

The men's inspection trip for the first time was not held as an official part of the meeting. Instead, to provide more program time, it was scheduled for Thursday afternoon, following the meeting adjournment. Some 180 made the trip to the Owls Head Pollution Control Project, located on the Brooklyn waterfront of New York Harbor. Much interest was exhibited in the many design and operational innovations represented in this newest unit in the New York City pollution control program.

Manufacturers' Exhibit

As a companion feature of the New York meeting, the Water and Sewage Works Manufacturers' Association showed new equipment and process developments in an exceptionally interesting and informative exhibit. All space allotted for displays was fully utilized by the various manufacturers to make the exhibit one of the outstanding features of the meeting.

BOARD OF CONTROL MEETS AT NEW YORK

Another year of steady progress was recorded at the 25th Annual Meeting of the FSIWA Board of Control, in the two sessions held during the New York convention. A total of 39 officers and directors answered roll call at the meeting of the 1952 Board on October 5, and 37 were present for the organization of the 1953 Board on October 9.

New Officers

Officers elected on October 5 to serve for the terms indicated were:

President: E. Sherman Chase, Boston, Mass., to October, 1953.

Vice-President: Louis J. Fontenelli, Garwood, N. J., to October, 1953.

Treasurer: W. W. DeBerard, Chicago, Ill., to October, 1953.

Director-at-Large: Kerwin L. Mick, Minneapolis, Minn., to October, 1955.

Constitution Amended

Important amendments to the Constitution and By-Laws provided for changes in quorum and voting requirements that will expedite the conduct of business by the Board, and for relaxation of the old limit on Honorary Members. There can now be one Honorary Member for every 350 Active Members, whereas the roster of Honorary Members was formerly limited to ten.

Other amendments provided more specifically for the filling of vacancies in the offices of Treasurer and Director-at-Large.

New Joint Committee

Federation participation was authorized in the new Joint Committee for the Advancement of Sanitary Engineering, to include representatives of ASCE, AWWA, APHA, ASEE, and the Federation. The committee will study educational and training requirements of sanitary engineers, their functional use in public health and military service, employment opportunities, and similar matters.

Salaries Report

A special report on sanitary engineering salaries in public employment contained specific recommendations for execution by the Member Associations of the Federation. The full text of the report will be found on pages 110–113 of this issue of the JOURNAL.

1952 Awards

Annual Federation awards, as conferred by the Board of Control, were presented at the Annual Dinner on October 8 by President Boyce as follows:

The Harrison Prescott Eddy Medal to Wen-Hsiung Li, John C. Geyer, George S. Benton, and Knut K. Sorteberg for their research papers "Hydraulic Behavior of Storm-Water Inlets."

The George Bradley Gascoigne Medal to Walter A. Sperry for his original and practical contribution on plant operation entitled "Detergents and Their Influence on Sewage Treatment."

The Industrial Wastes Medal to R. N. Giles, C. T. Nicholson, F. W. Scheineman, and R. J. Austin—all employed by the Standard Oil Company of Indiana—for their paper "Performance of a Gravity-Type Oil-Water Separator on Petroleum Refinery Wastes."

The Charles Alvin Emerson Medal to Frank Woodbury Jones, for his many years of loyal and praiseworthy service to the Federation. The presentation of this award was made by Mr. Emerson.

The Board also confirmed the following nominations for the 1952 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation: Harrison Hall (Arkansas), Don E. Bloodgood (Central States), Paul Bolton (Iowa), Francis W. Kittrell (Kentucky-Tennessee), Clarence Theodore Mudgett (Michigan), P. N. Daniels (New Jersey), Herman Glenn Baity (North Carolina), Ray E. Koon (Pacific Northwest), George Ashby Rhame (South Carolina), Winfield A. Mahlie (Texas), Walter F. Freeborn (Institute of Sewage Purification).

Emphasis on Research

The Executive Committee was directed to study means by which the Federation might emphasize its research activities. Consideration will be given to expansion of the headquarters staff, if necessary, to permit the Federation to serve in the stimulation of research where it is needed, in furnishing guidance to research agencies active in the field, and in facilitating information exchange among researchers. Recommendations are to be made to the 1953 Board for action.

Manuals of Practice

The Sewage and Industrial Wastes Practice Committee reported on the issuance of one new manual in 1952, and on the status of others. Manual No. 5 entitled "Air Diffusion in Sewage Works" was published in June, 1952, with sales approaching 1,000 copies in the first three months.

The manual "Paints and Protective Coatings in Sewage Works" is expected to be the next to be published. Steps were taken to reactivate work on the sewer maintenance and trickling filter manuals, and consideration will be given to the production of a manual on meters and controls.

Standard Methods of Analysis

Although some delays have been encountered, the tenth edition of "Stand-

ard Methods'' is still expected to be published in 1953. The new edition will include much new material, notably a section on analytical methods for industrial wastes. The Federation will participate as a publisher of the tenth edition with APHA and AWWA.

Committee Leaders Retire

The appointment of 1953 committees was marked by the retirement of three long-time committee chairmen who have rendered outstanding service for many years. Drs. Willem Rudolfs, W. D. Hatfield, and F. W. Mohlman, who withdrew from their leadership of the Research, Standard Methods, and Industrial Wastes Committees, were recognized by appropriate expressions of thanks from the Board.

Membership

The Secretary reported that the constituent Member Associations of the Federation reached a total of 37 with the admission in April, 1952, of the Nebraska Sewage and Industrial Wastes Association. Affiliation of the Association for Water Hygiene (Sweden) was also stated to be imminent. [This affiliation was consummated in November, 1952.]

Aggregate membership of all Member Associations at September 30, 1952, was reported to be 5,450, a record high. This is an increase of 6.1 per cent for the year.

Winners of the 1952 membership contests were the Florida Sewage and Industrial Wastes Association with a gain of 39 per cent, and the Central States Sewage and Industrial Wastes Association with a numerical increase of 52 members in the year ended September 30, 1952. Other contenders were the California, North Carolina, Ohio, New England, Pennsylvania, and Kansas associations. The race for both of the $100 prizes was unusually close.

Financial

Net worth of the Federation at December 31, 1951, as reported by the auditor, was $64,443. Current operations were reported by the Secretary to be generally in accord with the budget, with a modest addition to surplus being anticipated.

An increase of 20 per cent in JOURNAL advertising rates was authorized, however, to meet increased printing costs becoming effective in 1953 and 1954, and to accommodate the increasing flow of good technical material that is being submitted for publication.

Atlantic City in 1955

With Miami, Fla., and Cincinnati, Ohio, having been previously selected as the locations for the 1953 and 1954 annual meetings, respectively, the Board designated Atlantic City, N. J., as the site of the 1955 convention. The Ambassador Hotel will be headquarters.

An invitation from the Pennsylvania association for a future annual meeting in Philadelphia was referred to the Meeting Place Committee. Other invitations are on file from the Texas, California, Canadian, and Rocky Mountain associations.

E. SHERMAN CHASE NEW PRESIDENT

E. Sherman Chase, of Boston, Mass., became the thirteenth President of the Federation at the organization meeting of the 1953 Board of Control, held at New York City on October 9, 1952.

Following his early education in the public schools at Merrimac, Mass., Mr. Chase graduated in the class of 1906 from Massachusetts Institute of Technology, where he specialized in Sanitary Engineering.

Upon graduation from Massachusetts Institute of Technology, Mr. Chase served in various sanitary engineering

capacities until 1913, when he became Assistant Sanitary Engineer with the New York State Department of Health.

In 1920 Mr. Chase entered the employ of Metcalf and Eddy, consulting engineers of Boston, Mass., as Sanitary Engineer, a position he held until becoming a partner in the firm in 1927. In the latter capacity he has had extensive experience with an exceptionally wide range of sanitary problems for many municipalities and industries throughout the United States.

Mr. Chase is an Honorary Member of the Institution of Water Engineers (England) and of the New England Water Works Association, being a Past President of the latter. He is also a Fellow of the American Public Health Association and a member of the American Institute of Consulting Engineers, the American Society of Civil Engineers, the Boston Society of Civil Engineers, the American Water Works Association, and the Inter-American Association of Sanitary Engineering.

In addition to being a Director-at-Large on the Federation Board of Control (1951–52) and Vice-President of the Federation (1952), Mr. Chase has served as a 2nd Vice-President (1949–50), 1st Vice-President (1950–51), and President (1951–52) of the New England Sewage and Industrial Wastes Association. He is also a member of the New York Sewage and Industrial Wastes Association and the Pennsylvania Sewage and Industrial Wastes Association, and has served on the Federation's Awards Committee (1942–47; chairman 1947), the Executive Committee (1952), and the Meeting Place Committee (1952). He is at present a member of the last two and also of the Finance and Honorary Member Committees.

L. J. FONTENELLI ELECTED VICE-PRESIDENT

Louis J. Fontenelli, Superintendent of Sewage Treatment for the Rahway Valley (N. J.) Sewerage Authority, was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 5, 1952. With his operational and Federation background, and his experience in general sanitation and Member Association affairs, Mr. Fontenelli brings to the Federation leadership group a proven ability that promises much in helping to achieve its ever-expanding objectives.

Previous to assuming his present position, Mr. Fontenelli had been engaged in maintenance and power plant operation for the Aluminum Company of America at its Garwood, N. J., plant and as Chief Engineer in Charge of Operation, New Jersey Division, Knickerbocker Ice Company. His present assignment deals with administration of collection and treatment of sewage and industrial wastes for nine municipalities in New Jersey.

Besides being a Past-President of the New Jersey Sewage and Industrial Wastes Association, Mr. Fontenelli for the past three years has been a member of the New Jersey State Examining Board for the Licensing of Water and Sewage Treatment Plant and Water Distribution Superintendents. He has been a member of the Federation Board of Control (1949–51) and has served on the Legislative Analysis Committee (1948) and the Executive Committee (1950–51). He is currently a member of the Federation's Executive Committee and the Meeting Place Committee.

SPECIAL REPORT ON SANITARY ENGINEERING SALARIES *

By Earnest Boyce and W. H. Wisely

President and Executive Secretary, respectively, FSIWA

This report is offered in compliance with the directive of the Federation Board of Control on October 11, 1951, to the effect that the President and Secretary determine the means and extent to which the Federation should undertake a study of compensation of sanitary engineers engaged in public employment at the local to state levels, especially for comparison with similar work in private employment.

Salary data gathered by other national and state organizations are explored here in general fashion for sanitary engineers employed in (a) state and local health departments, and (b) municipal and local district sewage works. This was deemed necessary in order to reach any conclusions as to the justification and nature of action that might be undertaken by the Federation.

Reference Material

Many national and other organizations have undertaken recent salary surveys pertinent to the Federation's present interest, some of which are continuing such surveys periodically. The references listed at the end of this report do not include all that are available, and were selected because they are recent (since 1950) and authoritative. The data on public health engineers and sanitarians are particularly good. The sewage works operation salary data are not so complete, but they give fairly good geographical representation and are considered typical of present conditions.

The basis for judging the adequacy and propriety of salaries has been taken as the schedule adopted by the U. S. Civil Service Commission (2) for General Service grades. The following is the relationship of that schedule with the schedule of professional grades as adopted by ASCE (1):

ASCE Grade	General Service Grade	Base G.S. Salary
1	GS-5	$ 3,100
2	GS-7	3,825
3	GS-9	4,600
4	GS-11	5,400
5	GS-12	6,400
6	GS-13	7,600
7	GS-14	8,800
8	GS-15	10,000
9	GS-16	11,200

Salary Data

Public Health Engineers

Reliable salary data for state and local public health engineers and sanitarians are presented in Table I, which indicate that the median and minimum salaries of chief state sanitary engineers are too low for the ability and responsibility demanded. Correction is needed in the smaller and medium-sized departments, where ASCE Grade 7 (base salary $8,800) should be the absolute minimum.

The median and minimum levels are also low for state sanitary engineers other than chief engineers. The minimum ASCE Grade 1 (base salary $3,100) should certainly apply here. A median level in the order of ASCE Grade 5 (base salary $6,400) is definitely justified.

Municipal public health engineers are also deserving of better compensation than is shown by Table I. ASCE Grade 1 ($3,100) should be the minimum for professional personnel, and a median level at ASCE Grade 4 ($5,400) would be in order for engineers other than department heads.

* Approved by FSIWA Board of Control Oct. 5, 1952.

TABLE I.—Compensation of Public Health Engineers

Classification	Salary ($)			Prof. Rating[1]	Ref. No.
	Median	Max.	Min.		
Chief state sanitary engrs.	7,949	12,300	5,200	6	3
Municipal sanitation directors	6,500	10,000	3,864	5	5
State sanitary engineers	4,900	9,852	2,880	3	3
Municipal sanitary engrs.:					
Large cities	—	7,500	3,150	3	5
Medium cities	—	5,850	2,600	2	5
State sanitarians	3,900	8,940	2,400	2	3
Municipal sanitarians	—	5,748	2,100	1	5

[1] ASCE professional grade as applied to present U. S. Civil Service base salaries for comparable General Service grades, referred to indicated median salary.

TABLE II.—Compensation of Sewage Works Operators

Classification	Salary ($)			Prof. Rating[1]
	Median	Max.	Min.	
Waterworks personnel (9):				
Supts. or managers	—	12,500	3,360	—
Chief engineers	—	11,000	3,000	—
Other technical	—	7,800	2,820	—
Sewage wks., NE states (6):				
Over 100,000 pop.:				
Supts.	6,230	9,000	4,500	4
Chemists	4,300	6,650	2,950	2
Operators	3,030	3,725	2,334	—
10–100,000 pop.:				
Supts.	4,500	9,300	3,100	3
Chemists	3,500	4,000	2,700	1
Operators	2,660	4,200	1,800	—
0–10,000 pop.:				
Supts.	3,050	4,950	1,920	1
Operators	2,650	3,835	600	—
Sewage wks., Indiana (7):				
Over 100,000 pop.:				
Supts.	5,000+	—	—	4
Chemists	—	5,000	4,000	—
Operators	—	4,000	3,500	—
10–100,000 pop.:				
Supts.	—	5,000	2,500	—
Operators	—	3,500	2,000	—
0–10,000 pop.:				
Supts.	—	3,500	3,000	—
Operators	—	3,000	1,000	—
Sewage wks., California (8):				
Primary treatment:				
Chief operators	4,800	7,200	3,216	3
Operators	3,720	4,560	2,556	—
Secondary treatment:				
Chief operators	4,180	7,260	2,640	2
Operators	2,700	4,044	1,320	—

[1] ASCE professional grade as applied to present U. S. Civil Service base salaries for comparable General Service grades, referred to indicated median salary.

A favorable trend in the general increase of public health personnel salaries is reported (3) for the year 1950–51.

Sewage Works Operation Personnel

Recent data on compensation of sewage works operation personnel are given in Table II.

The range of management and technical salaries in the waterworks industry is to a substantially higher level than in the sewage field. This is undoubtedly a reflection of the greater extent of private ownership of waterworks. Engineering salaries in private employment are significantly above those in public employment (1).

It is obvious that sewage works salaries all along the line are below the levels consistent with the public investment involved, the responsibilities entailed, and the competency necessary for efficient management and operation.

The ASCE grades and base salary ranges as listed in Table III are suggested as being more appropriate and justifiable.

Conclusions

1. The high interest and activity among national professional engineering societies and other agencies appears to insure ample survey data on engineering compensation. There is believed to be no need for the Federation to engage directly in salary surveys.

2. On October 10, 1947, the Board determined that plant operation salary data could best be compiled by the Member Associations. This policy has been confirmed by the successful surveys made since by the New England, Pennsylvania, and California associations and by the Indiana State Board of Health.

3. Existing salary schedules for public health engineers and for sewage works operation personnel are definitely below levels commensurate with the character and importance of the services being rendered.

4. The implementation of salary increases in the proper quarters can best be accomplished by the Member Associations, because they are much closer to the state and municipal authorities who must take the desired action.

5. The first obligation of the Federation is to assist sewage works operation personnel in securing better compensation. Public health engineers are already receiving successful leadership from their own specialized professional organizations, so that the need for Federation support here is secondary.

TABLE III.—Suggested Sewage Works Personnel Salaries

Position and Population	ASCE Grade	Salary Range ($)
Plant supts.:		
Over 100,000	7–9	9,000–15,000
10–100,000	5–7	6,000– 9,000
0–10,000	2–5	4,000– 6,000
Chief chemists:		
Over 100,000	5–7	6,000– 9,000
10–100,000	2–5	4,000– 6,000
0–10,000	—	2,000– 3,000
Chief operators:		
Over 100,000	3–6	4,500– 7,500
10–100,000	—	2,500– 4,500
Shift operators:		
Over 100,000	—	3,000– 4,200
Under 100,000	—	2,400– 3,600

Specific Recommendations

1. The Federation should stimulate interest and action in its domestic Member Associations to bring about:

(a) Collection of more data on the compensation and employment conditions of sewage works operation personnel. Comprehensive surveys at 3-year to 5-year intervals are recommended.

(b) A closer relationship between Member Associations and state municipal leagues and other organizations of municipal officials. The creation of special committees in the Member Associations is suggested to make and maintain such contacts, to the end

that municipal officials may be better informed as to the high grade of personnel required in sewage works and as to appropriate levels of compensation and other benefits.

(c) Encouragement of Member Association support of increases in engineering budgets of state and local health departments, where such increases are needed to hold qualified personnel. Support by resolutions and by personal contact with state officials and legislators is recommended.

2. The Federation should give priority to the publication of salary data as they are compiled and released by the Member Associations.

3. The Federation, through its Committee on Qualifications of Operators, should collate the data produced by Member Associations for presentation in a periodic report similar to this, so that nation-wide progress may be evaluated from time to time.

References

1. ASCE, "Survey of Salaries for Civil Engineering Positions." *Civil Eng.*, **21**, 8, 37 (Aug., 1951).
2. NSPE, "Interim Report of Salary and Fee Schedule Committee" (June, 1950).
3. U. S. Public Health Service with APHA and Association of State and Territorial Health Officers, "Salaries of State Public Health Workers" (Aug., 1951).
4. Kimble, S. A., "Salaries of State Health Department Personnel." *Pub. Health Rep.*, **67**, 1, 26 (Jan., 1952).
5. Conference of Municipal Public Health Engineers, "Summation of Data Regarding Professional Status, Activities, Salaries, Etc." (1951).
6. Pennsylvania Sewage and Industrial Wastes Assn., "Report of Operating Salaries Committee" (1950). [See SEWAGE AND INDUSTRIAL WASTES, **23**, 7, 919 (July, 1951).]
7. Indiana State Board of Health, "Manpower Requirements for Sewage Treatment Plants in Indiana" (May, 1951). [See SEWAGE AND INDUSTRIAL WASTES, **24**, 1, 93 (Jan., 1952).]
8. California Sewage and Industrial Wastes Assn., *Quarterly Newsletter* (June, 1952).
9. AWWA, "Compensation of Water Works Personnel." *Jour. AWWA*, **43**, 9, 675 (Sept., 1951).

Reviews and Abstracts*

Some Experiments on the Estimation of Non-Ionic Detergents of Polyglycol Type in Sewage. By N. G. Heatley and Eileen J. Page. *Water and San. Eng.*, 3, 2, 46 (1952).

The method used is based on the formation of an insoluble compound with phosphomolybdic acid in the presence of barium in acid solution according to the procedure of Shaffer and Critchfield. The precipitate is washed and dissolved in 1 volume of 5N HCl plus 4 volumes of methyl cellosolve. The solution has a broad absorption in the ultra-violet with a peak at 310 mμ. The absorption at this wavelength is measured with a Beckman DU spectrophotometer. Amounts of detergents up to 150 μg. in 4 ml. can be determined with an error of about ±1 μg. However, even this would not be sufficiently sensitive or specific for estimating the amount of non-ionic detergent likely to be present in sewage and therefore methods for extracting and concentrating the detergent were considered. The sewage was buffered to pH 6.8. Sodium chloride was added. The detergent used was either Lissapol N alone or in combination with other detergents. The mixture was shaken with 10 ml. of ether in a separatory funnel and the ether layer run into a centrifuge tube and dried. The watery phase was extracted a second time with ether and added to the same centrifuge tube and dried. The combined ether residues were taken up with ethanol and warmed. The residue was then treated by the above barium phosphomolybdic precipitation method.

The blank value of raw sewage was a fraction of 1 p.p.m. with one exception. The effluent had a blank value of almost zero. The recovery of added Lissapol N showed a scatter between replicates, but any one value differed from the mean by more than 1 p.p.m. Teepol in 200-p.p.m. concentration reduced both the blank and the recovery of Lissapol N. Triton could not be completely extracted with ether; hence, it is important to know whether non-ionic detergents found in sewage behave like Triton or Lissapol N.

H. Heukelekian

Interpretation of Chemical Analyses of Sewages. By J. McNicholas. *Surveyor*, 111, 117 (1952).

Each of the analytical tests ordinarily performed on sewage, sludges, and effluents is briefly discussed. The ranges of values normally found for domestic sewage are given, with the significance of values above or below those usually encountered. Although the interpretations given are on the basis of British practice, much of the information is of value wherever the analyses may be performed.

The tests considered include oxygen consumed; B.O.D.; ammonia, organic, albuminoid, nitrate, and nitrite nitrogen; suspended solids; chlorides; alkalinity; and pH of sewage and effluents. Also, water, grease, nitrogen, phosphate, and pH of sludges. The effects of treatment upon each of these characteristics are discussed.

M. C. Rand

Discharge of Trade Effluents into Sewers. By William T. Lockett. *Surveyor*, 111, 285 (1952).

The article deals principally with means of legally controlling the volume and composition of industrial waste discharges. A very short section alludes to general methods of pretreatment at the source.

M. C. Rand

Drawings, Specifications, and Quantities for Sewerage and Sewage Disposal. By L. B. Escritt. *Surveyor*, 111, 259, 275, and 291 (1952).

This series of articles, written primarily for the guidance of junior engineers, consists of suggestions for the writing of contracts for sewerage and sewage disposal plants. Numerous common errors and

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

poor practices are brought out, with constructive criticisms for turning out contracts in a form which will be most useful to both the parties concerned. Although based on British practice, much of the content is equally useful in the United States. M. C. RAND

Design of Sewage Disposal Works for Small Towns. By R. C. CARTER. *Surveyor*, **111**, 87 (1952).

The article is intended primarily as a guide for engineers with limited experience in the design of small-scale works. The author's purpose is not to discuss all the important features of sewage works design, but rather to call attention to the points in which the design of small plants differs from that of larger works, and to certain matters which he feels are apt to be overlooked. The paper includes numerous suggestions on the design of settling tanks, screening chambers, biological filters, humus tanks, pumping stations, and sludge beds. M. C. RAND

Chemical Oxidation: Some Laboratory Experiments in the Treatment of Chemical Trade Waste. By G. TAYLOR. *Water and San. Eng.*, **3**, 1, 31 (1952).

At Huddersfield, England, wastes from dyestuff and allied manufacture process amounting to 4 m.g.d. (Imp.) with a 4-hr. permanganate demand (cold) of 450 to 500 p.p.m. are treated with lime to a pH of 8.2 to give a 25 per cent reduction. In order to increase the purification and render the waste more amenable to biological treatment after discharge into the municipal plant, it was treated chemically in the laboratory with activated carbon, bromine, and ozone. Activated carbon at 1,600 p.p.m. gave 50 per cent reduction of oxygen consumed value. Bromine additions at the point of appearance of excess residual bromine gave reductions of 16 to 23 per cent. Ozone added to alkaline waste gave 22.5 per cent reduction. Ozonation under acid conditions was about half as effective as under alkaline conditions. H. HEUKELEKIAN

The Effects of Synthetic Detergents on Sewage Purification: A Summary of Current Knowledge in England. By C. LUMB. *Water and San. Eng.*, **3**, 1, 7; and **3**, 2, 53 (1952).

The quantities of syndets present in sewage may reach a concentration of 50 to 70 p.p.m. or even as high as 100 p.p.m., on the basis of 25 g.p.c.d. (Imp.) water consumption. Analytical methods for the determination of detergents in sewage are not satisfactory.

The available evidence indicates that up to 100-p.p.m. concentration detergents do not interfere with sedimentation of sewage. Emulsification or solubilization of suspended matter does not take place to a significant extent at concentrations of detergents likely to be present. In general, it appears that dispersions stabilized by synthetic detergents may be rendered partially less stable through the action of hardness in the water plus the adsorption of the detergents on the suspended particles and thus may be eventually removed by sedimentation. Quantitative estimations on the basis of some theoretical considerations indicate that 14 to 16 per cent of the total potentially insoluble matter in sewage may be emulsified by synthetic detergents, increasing by that amount the load applied on secondary treatment processes.

Synthetic detergents have severe adverse effects on the acid precipitation of sewage containing considerable amounts of wool washing and yarn and piece scouring wastes. Precipitation processes employing alum or ferric salts will, however, not be affected in mixtures of sewage and wool scouring wastes employing synthetic detergents rather than soaps.

Studies on the B.O.D. of detergents have shown that some retard the initial oxidation of sewage, but eventually both detergent and sewage are oxidized. Others do not show even an initial retardation. Another group of detergents is not oxidized at all and has a retarding effect on B.O.D. Still others are not oxidized, but have no effect on the oxidation of sewage. Reduced efficiency of sedimentation plus the reduction in the biological oxidation due to some of the detergents is likely to result in a deterioration of the final effluent.

Synthetic detergents present in sludge in sufficient amounts reduce the efficiency of digestion and retard sludge drying. Reduction of the grease content of sludges through increasing substitution of soap by synthetics will produce a reduction in gas.

H. HEUKELEKIAN

Sanitation in the British West Indies. By C. L. Langshaw. *Surveyor*, **111**, 99 (1952).

The published article consists of extracts of a paper delivered to the Institution of Sanitary Engineers. It describes the work of the Public Health Engineering Unit of the Windward and Leeward Islands from 1944 to 1950.

The conditions encountered by the Unit at the outset of its work were, briefly, an almost complete lack of sanitary facilities. Even reliable surveying data were unavailable. Personnel were untrained and inadequate in numbers. The situation is illustrated by the results of a survey conducted in 1949 in one of the largest and most advanced of the islands, which showed that 35 per cent of the houses were overcrowded by central housing authority standards, 90 per cent were without water supply, and 67 per cent were without private latrines.

The work of the Unit during the 7-year period considered dealt with surveying, the improvement of housing, water supplies, drainage of both surface and foul waters, sewage disposal, and malaria control. A very important task was the training of natives as engineering and field assistants. There are many illustrations of the ingenuity required in overcoming not only the serious sanitary problems involved, but also the financial problems which it appears were often even more perplexing.

M. C. Rand

A Study of the Biology and Control of *Anisopus fenestralis* (Scopoli 1763), a Fly Associated with Sewage Filters. By H. A. Hawkes. *Ann. of Appl. Biol.*, **38**, 3, 592 (1951).

Experiments showed that limiting the food supply had an effect on the life cycle of *Anisopus fenestralis*. Decreasing the food concentration increased the duration of larval phase, had no effect on the duration of pupal phase, but decreased the size of pupae and decreased the duration of adult phase when not fed, but increased the duration of adult phase when fed. Experiments conducted with different types of trays used for trapping the flies showed that all metal bottom traps inhibited the migration of the flies into the trays and that the number of flies trapped in the surface trays gave no true measure of the emergence of flies from the filter. It was also shown that flies migrated into the trays from areas outside the space covered by the trays when conditions did not favor emergence. It was concluded that the flies sought shelter in the trays from surrounding areas when climatic conditions were unfavorable for their emergence. In daylight and in cold weather the flies tend to keep to the warm dark depth of the filter and only few enter the trays. Increase in temperature and decrease in light intensity result in larger numbers being present at the surface and hence the numbers trapped increase. When conditions favor emergence, even though there may be large numbers present at the surface, few enter the trays. The emergence is better measured by the use of traps above the filter such as canister traps or by sticky surfaces. Estimates of flies in the filters may be obtained by counting the larvae and pupae in the filter.

Studies on the seasonal incidence of *Anisopus fenestralis* show by tray trappings that the period of maximum abundance in the filter is during the spring and that throughout the summer months the numbers are reduced. An increase occurs in the autumn and large numbers are found throughout the winter. Above the filter the fly was present in large numbers only during the warm periods when mean temperatures exceeded 52° F. During the warmer periods there appear to be two periods of abundance, one in June and another in the autumn.

Experiments on the control of flies with benzene hexachloride showed that the emulsion form was less effective in the control of flies than the same chemical applied as a dispersible powder. The chemical was most effective when used against the larval stage and least effective against the pupal stage.

H. Heukelekian

Factors Influencing the Egress of Sewage Fly *Anisopus fenestralis* from Bacteria Beds. By H. A. Hawkes. *Proc. Birmingham Nat. Hist. and Phil. Soc.*, **18**, Part III, 41 (1952).

This deals with the aerial density of *Anisopus fenestralis* over the filter bed (4 ft. elev.) as measured by trappings on sticky surfaces. The fluctuations in the number of flies trapped were considered to be due to climatic conditions influencing the egress of the flies from the bed, rather

than to fluctuations in fly population in the bed. The results showed that during the colder periods the egress of flies was inhibited. A study of the maximum air temperatures during colder days showed that the numbers of flies were limited when temperatures were 52° F. or below. Above this temperature the numbers increased regularly. However, on certain occasions with temperatures above 52° F. only a few flies were trapped, indicating that there were other factors involved. One of these factors was shown to be wind velocity, which gave an inverse relationship with the numbers of flies. With wind velocities of 20 to 25 m.p.h. there were only negligible numbers of flies. It was also shown that light inhibits the egress of flies, the egress being greatest at dusk and decreasing rapidly during the dark.

H. HEUKELEKIAN

Depth: A Possibly Major Factor in Percolating Filter Design. BY L. B. ESCRITT. *Surveyor*, **111**, 143 (1952).

As the rate of flow through a trickling filter is increased, the water retained per cubic yard of medium increases to a maximum, and then falls off. The author's calculations, from data first presented in "Water Pollution Research, 1950," show that the maximum water retention occurs at about 1,000 g.p.d. (Imp.) per square yard of filter surface.

At the optimum rate of flow, resulting in maximum retention of liquid, the filter should be capable of doing more work than at other rates of flow. This reasoning is supported by data cited. The B.O.D. removal, in pounds per cubic yard per day, was greatest at the optimum flow.

It may, therefore, be suggested that with any given quantity of filter medium, an optimum result can be obtained by so arranging the depth or otherwise operating the filter that an optimum rate of flow per square yard of surface is maintained. This has been done in practice, although unconsciously, by various methods, including recirculation, alternating double filtration, and the construction of deep enclosed filters. It is shown in this paper that the increased efficiency of purification realized by each of these means can be explained on the basis of their having attained or approached the optimum rate of flow per square yard of surface.

Further analysis of the data shows that the performance of the filters was in direct proportion to the amount of water retained in the medium, and that presumably the rate of flow per square yard of surface was the only factor responsible for the increased efficiency. If further investigations should support this contention, then the depth of a filter becomes a factor of major importance in design, instead of being purely arbitrary, as has formerly been the case. M. C. RAND

The Condition of the Tidal Portion of the River Thames. BY C. J. REGAN. *Water and San. Eng.*, **3**, 2, 58 (1952).

The analytical work in the past 60 yr. on the tidal section of the Thames River, covering a distance of 67.5 mi. below London Bridge, is summarized and discussed. The trend toward deterioration of river condition as indicated by D.O. saturation and an increase in ammonia nitrogen content is clearly shown. During the summer low-water period (July to Sept.) the D.O. below the Southern and Northern outfalls, both at high and low water, has been extremely low in recent years. The D.O. content increases again further down in the estuary. At high tide "nil" D.O. was found down to 26.5 mi. below London Bridge and at low tide to 33 mi. below the same point. The incidence of the complete absence of D.O. has increased in recent years. Another interesting but adverse trend is the increase in water temperature over the past 60 yr. which is not due to increase in air temperature.

The oxygen demand load on the river from the Northern and Southern outfalls decreased during World War II, due to evacuation, but the conditions in the river did not show an equivalent improvement. After the war the load increased again and the deterioration continued. A program of pollution abatement was set up in order to maintain D.O. in the river at all times off the outfall. The program consists of: (a) construction of detritus pits in the Northern outfall, nearing completion; (b) new primary sedimentation tanks at the Northern outfall, to be completed in about a year; (c) new diffused air activated sludge plant with 60-m.g.d. capacity at Northern as well as Southern outfalls; (d) sludge digestion at Northern and Southern outfall works to treat all

the sludge produced. The progress of the latter items is dependent on the issue by the Government of necessary licenses.

H. HEUKELEKIAN

Application of Molecular Filter Membranes to the Bacteriological Analysis of Water. BY ALEXANDER GOETZ AND NOEL TSUNEISHI. *Jour. Amer. Water Wks. Assn.*, **43**, 12, 943 (1951).

This detailed paper is based on work done for the Biological Dept., Chemical Corps, U. S. Army, under contract with the California Institute of Technology and covers investigations over a 3-year period on methods of producing molecular filter membranes in an improved manner. A number of standardized types of such membranes derived from cellulose nitrate and cellulose acetate, one of which is especially designed to fulfill the requirements of standard methods of water bacteriology, were then developed. Investigations further revealed that bacteria and other particles were retained on the surface of the filter. Additional work developed methods and equipment for filtration and also improved use of nutrients and inhibitors.

The following conclusions suggest that use of the molecular filter in the field of water bacteriology has numerous distinct advantages of primary importance to sanitary engineers:

1. It permits the concentration of a small number of organisms from large quantities of water, thereby increasing the accuracy and reliability of such determinations.
2. It minimizes cross-diffusion and spreading of colonies, and, consequently, allows the combination of any number of bacteria, from a few to 5,000 at one time. This has the advantage of reducing the number of laboratory dilutions and duplicate incubations.
3. It permits separation of the organisms from their nutrient at any time, for the purpose of either changing the nutrient or partially or totally inhibiting further development.
4. It gives a direct count instead of a most probable number in the determination of lactose-fermenting bacteria, such as the coliform organisms.
5. It saves time in comparison with present standard procedures.
6. It requires much less laboratory space and practically no glassware.
7. It permits better and faster differentiation of bacteria.
8. It gives a permanent record in the form of the preserved filter disks.

The molecular filter technique, as improved and developed at the California Institute of Technology laboratories during recent years, promises to render the practices utilized by sanitary engineers in water analysis more efficient and economical.

Discussion

Paul W. Kabler—Work with the molecular filter at the Environmental Health Center of the U. S. Public Health Service is described in this discussion. It is brought out that aside from experiments designed for the acquisition of basic technique and experience, little of the authors' work was repeated. Work at the Environmental Health Center has comprised intensive investigation of bacterial count, quantitative estimation of the coliform group, and the culture of *Salmonella typhosa* from water.

Lee Streicher—The studies of the Metropolitan Water District of Southern California on known media formulas in use with the molecular filter are described. The modified Gassner broth of Goetz and the modified Endo broth referred to by Kabler were the two types of media tried. It was concluded that neither of these nutrients appeared to be satisfactory on raw Colorado River water and that further development of media is needed for use on the water of the Metropolitan Water District.

Harry G. Neumann—This detailed discussion covers research on the molecular filter by the Los Angeles Department of Water and Power. Many different aspects of the use of these filters are mentioned. In particular, the initial saving in time afforded by concentration and culture in place provides an excellent opportunity to use some of the techniques for determination of sanitary quality which are now confined to investigative work. Another important point is the possible use of the molecular filter method for the development of a quick satisfactory emergency test. Combination with other techniques is also described. However,

experiences with treated distribution waters of the Los Angeles system have not been satisfactory for bacterial concentrations, as indicated by these early studies. ROBERT P. LOWE

Municipal Incineration. San. Eng. Res. Project, Inst. of Eng. Res. Series 37, Univ. of California. Tech. Bull. No. 5, 110 pp. (June, 1951); Tech. Bull. No. 6, 77 pp. (Nov., 1951).

Bulletin No. 5 contains much preliminary and incidental information to an understanding of incinerator design and plant operation tests. The results of a "use" survey of installations in the United States are reported. Following chapters discuss, often sketchily, characteristics of municipal refuse, principles of combustion, utilization of waste heat, incinerator location, general features of buildings, and handling and storage facilities. Other chapters cover furnaces and chambers, ash handling, stacks, and refractories, and while not in technical detail, are descriptive and include diagrams and pictures. The appendix contains a glossary, discussion of contract documents and specifications, and sample thermodynamic calculations.

Bulletin No. 6 gives details of the method of study, a summary of data obtained, and the results of calculations, for surveys at three California municipal incinerators. Two handled only combustible refuse, but the other included garbage. General data on control and operation were collected for one week on each. During this period a 2-hr. test was run where samples were taken, air flow and temperatures measured, and where other information ordinarily not collected was obtained. The arrangement and construction of each unit, especially that of combustion chambers and flues, is given.

The results of heat and mass balance, heating values for refuse, and the week's performance data are given for each test. Results of test data are shown in a comparative table, and the continuous-recording charts of gas and refractory temperatures and of analyses of dry gas are reproduced. Calculations are shown for the method of computing the heat and mass balance for one of the tests. There are also a number of graphs and a discussion covering particle size distribution of stack discharge. WM. A. HASFURTHER

Sewerage and Sewage Disposal in 1951. ANON. *Surveyor*, 111, 127 (1952).

England's general position in regard to sewerage and sewage disposal was no better, and probably worse, than during the previous year. The greatest difficulty was lack of funds, making it impossible to keep abreast of the requirements for maintenance and for new construction. The condition was aggravated in many localities by an acute labor shortage.

Research, on the other hand, continued quite active. The work of the Water Pollution Research Laboratory was especially noteworthy, in both amount and variety. Important contributions were also made by individual sewage works.

An important piece of legislation enacted during the year is known as the Rivers Act of 1951. Essentially, it provides clear-cut regulations on stream pollution and its prevention, for the guidance of the River Boards created in 1948. The new act is particularly welcome in that it replaces several hundred years' accumulation of piecemeal legislation. One of the most important clauses empowers the River Boards to prescribe standards for all effluents discharged within their respective areas. Thus, rather than a nation-wide effluent standard, there will be standards adjusted to the capacities and uses of the individual streams. An amendment appended to the act before its passage is still the subject of considerable controversy. As originally drafted, the bill made the River Board standard the final criterion as to whether an effluent was satisfactory. In effect, this assured an industry or municipality that so long as this standard was met, there would be no danger of successful complaints from downstream. The amendment reverses this position, making it possible for riparian interests to take proceedings for pollution or nuisance under common law. The general opinion seems to be that the amendment is rather unfortunate, because it offers no assurance that a certain degree of treatment will be adequate without question.

The River Boards themselves were still in the process of organization, and although some had begun their work, not a great deal of tangible progress in pollution abatement had been made. This fact was due in part to the previously mentioned shortage of funds and labor for

the construction, maintenance, and operation of purification facilities.

One of the most important jobs facing the River Boards is the establishment of effluent standards. This implies, among other things, the selection of the tests to be used. The B.O.D. test, which is in rather general use and favor, has certain disadvantages which give rise to some objection to its use as a standard. Bioassay tests for toxicity have also been considered to some extent.

There were no outstanding developments in sewerage during the year.

The report discusses a number of papers which appeared during the year, treating various phases of sewage works design, and which have been previously reviewed here. M. C. RAND

Sewage Works Construction by Direct Labor in the Ploughley (Oxon) Rural District. BY J. A. HARVEY. *Surveyor*, **111**, 133 (1952).

The article describes the construction of a medium-sized sewage treatment plant. Rather than employing a contractor, the work was done by gangs of laborers supervised by the staff of the county surveyor. Completing the operation without the skilled labor and heavy equipment which would be available to a contractor required interesting and ingenious improvisations, which are explained in detail. M. C. RAND

Facts and Fallacies of Sedimentation. BY L. B. ESCRITT. *Surveyor*, **111**, 203 (1952).

Although sedimentation has been long used, and much studied, as a means for the removal of suspended solids from both sewage and trade wastes, the interchange of knowledge on the subject has not been satisfactory. The empirical rules of design, which were used very generally until recently, and which still have considerable influence, lead to results which are usually sufficient, but to poor economy of construction.

If it is necessary to increase the detention period to remove a particle, it must be done by increasing the surface area, since an increase of depth, although it increases the detention period, proportionately increases the distance through which the particle must fall.

Experiments have shown, however, that the efficiency of sedimentation varies as the fourth or fifth root of the surface area of the tank. Great changes of surface area, therefore, produce relatively small changes of efficiency. There are other means by which the efficiency may be increased more economically.

The inlet must be of such a type that the velocity head of the sewage is dissipated, as much as possible, before the sewage enters the tank, and the sewage must enter at low velocity. Both the inlet and the over-all proportions of the tank must be designed to avoid velocities high enough to cause turbulence of such intensity as to interfere with sedimentation.

The position of the outlet weir may greatly affect the efficiency. The best arrangement is to remove the effluent in a thin film from the surface, in a position where the least concentration of suspended solids exists. The usual arrangement, of having the outlet weirs at the top of the tank walls, is not ideal, since currents impinging on the walls below the weirs cause comparatively high upward velocities, tending to lift sludge toward the weirs. A better arrangement is to have the weirs at a distance from the walls, so that sludge lifted by the currents at the walls may settle again before reaching the weirs.

Particles too small to settle may flocculate, or gather together into clumps of settleable size. This action can be encouraged by the use of chemical coagulants or by gentle stirring. The upward flow tank takes advantage of this effect by passing the entire mass of liquid through a sludge blanket, which in effect strains out many particles too small to settle by themselves. The velocity of upward flow must be less than the falling velocity of the sludge. Upward velocities at maximum flow of from 4.5 to 9 ft. per hour are the values commonly used in design. M. C. RAND

Construction of Sewage Works Without Steel. BY L. B. ESCRITT. *Surveyor*, **111**, 233 (1952).

Although the author's comments are inspired by the shortage of steel in England, and the resulting difficulties of sewage works construction there, many of his suggestions may be equally applicable in the United States. Not only do steel shortages arise here from time to time, but

it is shown how, in certain parts of the sewage works at least, the use of mass concrete and brickwork may actually reduce construction costs. The title is slightly misleading in that no scheme is presented for construction totally without steel; rather, the article points out how steel requirements may be minimized.

Tables are presented which show the thickness of mass concrete required for manholes, tank walls, and floors. There are numerous suggestions for reducing the quantities of steel required in the construction of primary and secondary sedimentation tanks, grit chambers, and digesters, and even of trickling filters, screens, and pumping stations.

The extent to which steel can be spared depends on the size of the plant. Small works, not extensively mechanized, permit greater percentage economy than do large works, which must be mechanized for efficient operation.

Many designers, in the author's opinion, have formed the habit of specifying reinforced concrete, not only where it is the most suitable material, but wherever it can be used. He reminds such designers that at one time very little steel was used for structural purposes, and that many old works, built without reinforcement, remain. M. C. RAND

Some Observations on the Performance of Very Small Sewage Works. By L. B. ESCRITT. *Surveyor*, **111**, 351 (1952).

Up to the present, many small country premises have discharged untreated or poorly treated effluents into small streams, but it is expected that the time will come when such discharge will not be permitted. As a result of lack of knowledge of methods of sewage treatment on the part of those who are often concerned with the construction of small works, many of them produce very unsatisfactory effluents or cause nuisance. In many cases, total neglect of the works contributes to the poor results obtained.

Originally, septic tanks were designed for the settlement of sewage and storage of the sludge so as to reduce its quantity by digestion. They remain the most satisfactory means of settling at small private works, simply because they are designed for infrequent desludging. However, they are frequently expected to destroy the sludge completely by digestion, and to perform some purification in addition to removal of the sludge—functions which they do not and cannot perform. The author suggests that the capacity of a septic tank should be based on the period between desludgings, and upon the population served, allowing for one-half the tank's capacity to be occupied by the solids accumulated between cleanings. He further suggests that no tank should have a capacity of less than 1,000 gal.

Where percolating filters are used, the recommended size is 0.5 to 0.67 cu. yd. per capita. Effective distribution and adequate ventilation must be provided, and medium of 2-in. size is preferable to finer grades, being less subject to clogging.

If the levels necessitate pumping, it is best to pump after sedimentation, or to pump the filter effluent. Small wet wells are advisable before the filter, to improve distribution.

Humus removal may be effected by secondary sedimentation, or by irrigation over a suitable area of land. When properly designed, small private works are capable of producing excellent effluents. M. C. RAND

National Policy on the Discharge of Trade Effluents into Public Sewers. Inst. of Sew. Purif. Memorandum. *Surveyor*, **111**, 413 (1952).

In a memorandum approved by the Council of the Institute on May 23, 1952, the Institute has set forth in considerable detail its policies on this important question. The quotations below are from the section dealing with the basic concepts which form the foundation of the policy, and from the conclusions of the memorandum. References to specific legislation are purposely omitted here, being considered of less general interest than the broad principles set forth.

"5. The conclusions and recommendations recorded in this Memorandum are based on the following conceptions of policy which the Institute believes to be in the best interests of all concerned:

"(a) The Institute recognizes that the prosperity of the country depends on the prosperity of its industries, and that everything must be done to help industry to solve its problems of trade effluent disposal.

"(b) The Institute wholeheartedly ac-

cepts that the sewage works is the best and proper place for treating all suitable trade waste, and that the pollution of rivers by industry can be most effectively prevented in that way.

"(c) It is in the interests of the community, and therefore of traders themselves, that sewage works shall be operated at the maximum efficiency and with the greatest economy.

"(d) The possibility of purifying sewage at reasonable cost to produce an effluent of the standard necessary . . . today is dependent on the use of biological processes. These provide by far the cheapest method of dealing satisfactorily with this problem . . . .

"Moreover, biological processes are adaptable to dealing with trade wastes of large variety if these wastes can be adequately diluted by domestic sewage. Since biological processes, however, depend on living organisms, there is ultimately a limit to the conditions which they can tolerate, and therefore there will always be some effluents which, because of their quantity or composition, cannot be accepted by the sewage works without damage to purification processes.

"Equally it is necessary to take precautions to prevent damage to sewers and injury to workmen, and to avoid difficulties in the operation of other processes used in sewage treatment.

"(e) To provide adequate safeguards, it is essential in a minority of cases that industry should adopt some form of pretreatment, or to modify manufacturing processes . . . . The Institute advocates the utmost collaboration between the local authority and the trader on such matters. . . .

"Exceptionally, there will be a few cases where the problem of trade effluent disposal is such that the possibility of its solution must control the location of the industry itself . . . . It can never be right that a vital public health service should be jeopardized, and that a sewage works should possibly be put completely out of action because of the waste from perhaps only one factory, nor that the cost of sewage treatment for a whole town should be seriously increased by any such discharge.

"(f) The Institute is of the opinion that where a local authority decides to make a charge for the treatment of trade effluents, it should be ready to render this service to the trader in the public interest on the basis of payment only for the cost incurred.

"47. The following is a summary of the conclusions of the Institute on these matters:

"(a) That the objective . . . of bringing about an improvement in the condition of rivers . . . can be readily achieved so far as the purification of domestic sewage is concerned, but that complete success will depend on proper treatment being applied to trade effluents from industrial sources.

"(c) That if sewage works are to be operated at their maximum efficiency, and with the greatest economy, and are to give the best service to the manufacturer in providing treatment for trade effluents, it is most necessary that the whole of the effluents discharged into sewers should be under proper control." M. C. RAND

The Sewage Treatment Plant at Beverwÿk (Holland). By J. J. HOPKINS AND L. H. OP TEN NOORT. *Publieke Werken*, No. 10, 1 (1951).

Raw sewage from a population of 28,500 and industrial waste with a population equivalent of 30,000 discharged into a land-locked harbor created serious nuisances for a number of years. The seasonal nature of some canning industries and the presence of waste from chemical industries made the solution of the problems difficult. The plant, designed for an equivalent population of 80,000, provides grit removal, comminution, preliminary settling, aeration (brush aerators), intermediate settling, trickling filters, final settling, and sludge digestion.

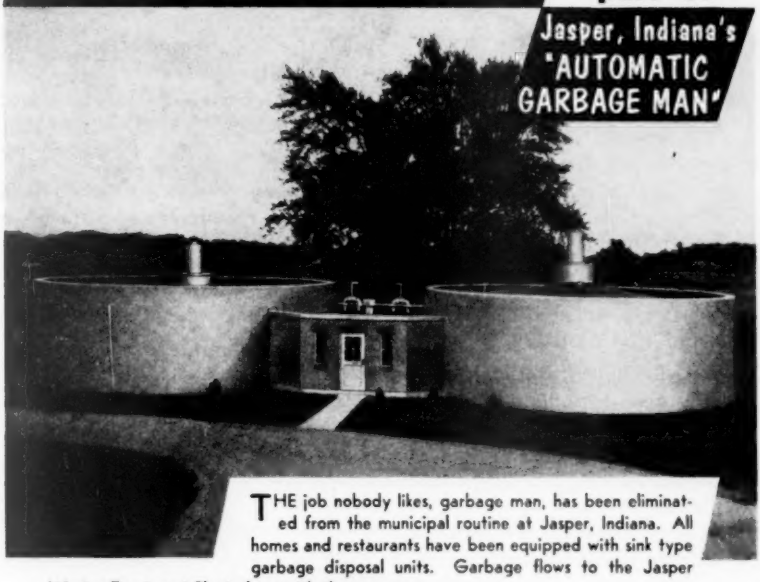
W. RUDOLFS

Preliminary Studies on Municipal Night Soil Digestion. By ISAMU HORASAWA. *Bull. Inst. Public Health* (Japan), 1, 2, 26 (1951).

Municipal night soil digested without seeding within 75 days at 30° to 35° C. Seeding reduced the digestion period considerably. The volume of gas produced was 300 to 500 ml. per gram of volatile solids. The B.O.D. of the supernatant liquor varied from 765 to 1,170 p.p.m.

H. HEUKELEKIAN

P.F.T. CONTROLLED DIGESTION is a vital part of Jasper, Indiana's "AUTOMATIC GARBAGE MAN"



THE job nobody likes, garbage man, has been eliminated from the municipal routine at Jasper, Indiana. All homes and restaurants have been equipped with sink type garbage disposal units. Garbage flows to the Jasper Wastes Treatment Plant along with the sewage.

P.F.T. Controlled Digestion is a vital part of the plant. It assures effective digestion of garbage and sewage solids and maximum utilization of the increased quantities of sludge gas produced due to the addition of the garbage solids. Controlled Digestion, at Jasper, includes two 40' - 0" diameter P.F.T. Floating Cover Digesters with total capacity of 68,840 cu. ft. . . . a P.F.T. #250 Digester Heater and Heat Exchanger equipped for gas and oil firing, with type "C" controls. . . . P.F.T. Supernatant Selectors in both digestion tanks with Supernatant Liquor Gauges, Sight Glasses and Samplers in the Control Room . . . . a full complement of P.F.T. Gas Safety Equipment for safe transmission and utilization of sludge gas.

Optimum temperature in the digester tank is highly important and is assured by the automatic controls of the P.F.T. Digester Heater and Heat Exchanger.

The plant is designed for a population loading of 10,000. Couch & Kulin, Consulting Engineers, Indianapolis, Ind., designed the plant.

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Proceedings of Member Associations

CALIFORNIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 24th Annual Convention of the California Sewage Works Association was held at the Casa del Rey Hotel, Santa Cruz, Calif., on April 23–26, 1952. Registration during the afternoon of April 23 was followed by an evening hospitality hour get-together at the Fun House on the beach.

The technical sessions on April 24 featured the following papers:

"How Best Can Industry and the C.S.W.A. Cooperate," by a panel consisting of Jack McKee, Associate Professor of Sanitary Engineering, California Institute of Technology; Luther Nichols, of the Industrial Wastes Committee, California Manufacturers' Association; Herbert C. Davis, President, California Association of Production Industries; and Arthur Pickett, Industrial Wastes Engineer, Los Angeles County.

"Wastes Disposal at the Fontana Steel Plant," by H. I. Riegel, Superintendent of Utilities, Kaiser Steel Corp., Fontana.

"Practical Solution of Two Industrial Wastes Discharge Problems," by Russell Ludwig, Ludwig Brothers, Pasadena.

"The Spirovortex Activation Process and its Utilization at Turlock for Industrial Wastes Treatment," by John H. Jenks, with Harry N. Jenks, Consulting Engineer, Palo Alto.

"Experience with Recirculation Ponds of the Modesto Treatment Plant," by M. B. McKinnie, formerly Superintendent of Sewage Treatment, Modesto.

"Laboratory Organization and Technique for Large-Scale Sewage and Industrial Wastes Testing," by Nathan J. Krotinger, Materials Testing Assistant, Los Angeles City Bureau of Standards.

The April 25 morning session opened with three concurrent breakfasts—one each for engineers, operators, and sewer maintenance personnel. Discussion leaders for these open forums were, respectively, H. B. Gotaas, Professor of Sanitary Engineering, University of California, Berkeley; H. C. Parker, Superintendent, sewage treatment plant, Riverside; and A. A. Appel, Superintendent, Sewer Maintenance Division, Bureau of Sanitation, Los Angeles.

The operators then attended an "Operator's Forum," at which the following papers were presented:

"Grit and Chlorination Problems at the Santa Cruz Plant," by Anthony Bell, Chief Operator, sewage treatment plant, Santa Cruz.

"The Problem of Being Both a Sewage Plant and Sewer Maintenance Superintendent," by James O. Groves, Superintendent, Mount Vernon Sanitation District.

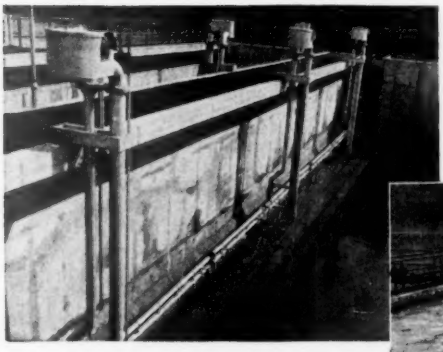
"Corrosion in a Fairly New Digester," by Ludwig Huebner, Chief Operator, sewage treatment plant, Palo Alto.

"The Use of Digester Gas in Operating Gas Engines," by E. J. Dillashaw, Superintendent, North of the River Sanitation District.

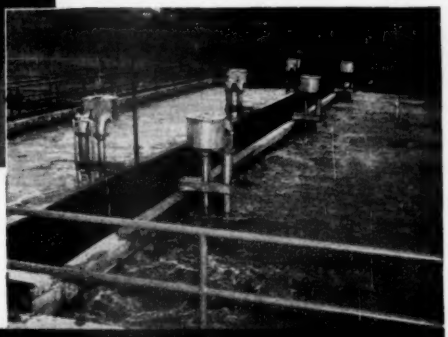
The afternoon session heard the following papers:

"Control of Sewage Chlorination by

(*Continued on page 24a*)



DIFFUSAIR installation at Kirkwood, Mo. Impingement nozzles and bowls are on headers at lower left side of tank.



DIFFUSAIR at Kirkwood, Mo. in operation showing effective "spiral flow" agitation and aeration of tank liquor.

impingement aerator **DIFFUSAIR**

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The Impingement Aerator is a unit developed to accomplish more effectively and economically the diffusion of air as small bubbles to agitate and oxygenate aeration tank liquors.

The principle involved is the combining of a low velocity jet of tank liquor and large air bubbles within an open bowl-like impinger. The cavitation effect thus produced divides the air into smaller bubbles than those diffused from a No. 30 permeability porous tube. The amount and pressure of the impingement water is very low when compared with the progressive back pressuring of the blower that persists when other types of air diffusers are employed.

The impingement liquor is derived directly from the aeration tank mixed liquor, and is lifted with a simple air-lift unit from which 1/3 of the fine air is re-entrained and utilized for oxygenation.

The air is released along headers through 3/16 inch orifices in the impinger units and no air clogging is possible. No filtering of the compressed air supply is required since there are no fine diffusion pores to become clogged.

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Amperometric Titration," by W. L. Henderson, Chief Chemist, Orange County Joint Outfall Sewer.

"Storm Water in Sanitary Sewers," by V. W. Sauer, formerly General Manager, Central Contra Costa County Sanitation District.

"Functional Aspects of Sewage Plant Instrumentation," by J. Betz, Civil Engineer, Hyperion sewage treatment plant, Los Angeles.

The Annual Banquet and Dance, held the evening of April 25, was enjoyed by the members and their ladies. The meeting closed on April 26 with visits to various sewage treatment plants and other points of interest.

At the Business Luncheon on April 25, an amendment was made in the constitution to change the name of the Association to the California Sewage and Industrial Wastes Association.

Officers elected to serve during 1952–53 were:

President: A. G. Pickett, San Marino.
1st Vice-President: L. H. Cook, Menlo Park.
2nd Vice-President: A. A. Appel, Los Angeles.
Secretary-Treasurer: Sam A. Weed, Oakland.

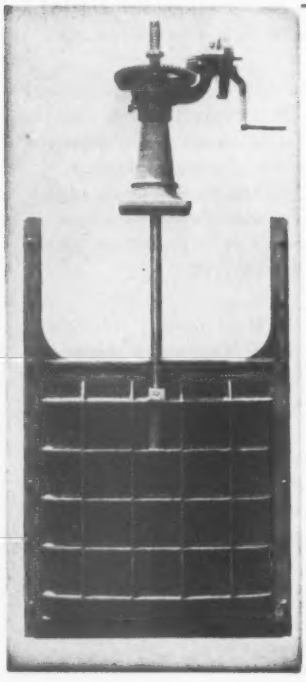
SAM A. WEED,
Secretary-Treasurer

LOUISIANA CONFERENCE ON WATER SUPPLY AND SEWERAGE

The 1952 Annual Meeting of the Sewage Works Section, Louisiana Conference on Water Supply and Sewerage, was held at Louisiana State University, Baton Rouge, La., on March 19–20, 1952, in conjunction with the 15th Annual Short Course.

The program stressed the Controlled Materials Plan, civil defense, and equipment operation and maintenance.

(*Continued on page 26a*)



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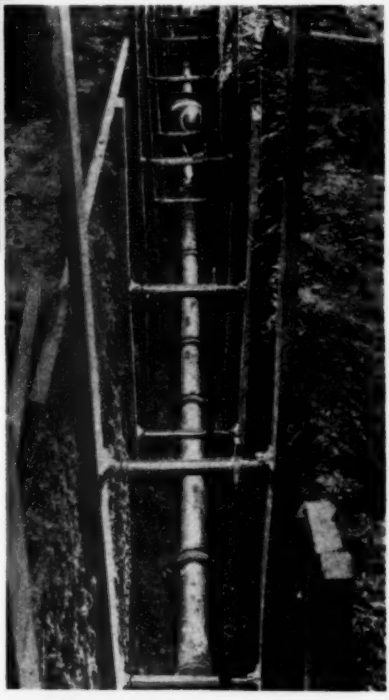

CLAY PIPE gets another 72-Mile Testimonial

Here's a testimonial 381,000 feet long, proving once again that Vitrified Clay Pipe is the time-tested material engineers and public officials depend on for sanitary sewerage. Thanks to their foresight, thousands of new homes in the San Jose district, as well as essential housing projects throughout the nation, will enjoy the *permanent* sanitary protection that only clay pipe can offer.

Vitrified Clay Pipe assures generations of trouble-free service. Acid sewage or alkaline soils can't corrode it . . . time can't weaken it. It's the only chemically inert sewerage material — *the only pipe that never wears out!*

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Detroit, Mich. (Jet Engine Plant)	28,000 ft.
Topeka, Kan. (Private Housing)	13,000 ft.
Tucson, Ariz. (Municipal Expansion)	38,000 ft.
Minneapolis, Minn. (Private Housing)	80,000 ft.

C-1252-59

Officers elected for the ensuing year were:

Chairman: J. C. Pittman, Houma.
Vice-President: A. J. Meyers, Norco.
FSIWA Director: J. J. Holtgreve, Metairie.
Secretary-Treasurer: G. H. West, Lake Charles.

G. H. WEST,
Secretary-Treasurer

CENTRAL STATES SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 25th Annual Conference of the Central States Sewage and Industrial Wastes Association was held at the Loraine Hotel, Madison, Wisconsin, June 25–27, 1952. 208 persons registered for the meeting, of which 42 were ladies.

The afternoon session on June 25, included the following papers:

"Financing Sewage Treatment Works," by Arndt J. Duvall, Sanitary Engineer, Tolz, King and Day, St. Paul, Minn.

"A Rational Approach to the Industrial Waste Disposal Problem," by Roy N. Giles, Director of Technical Service, Standard Oil Company (Indiana), Chicago, Ill.

"Studies on Seeding Techniques in the B.O.D. Determination," by Raymond G. Zehnpfennig, Research Associate, and M. Starr Nichols, Chief Chemist, State Laboratory of Hygiene, Madison, Wis.

"Studies on Chemicals with Selective Toxicity to Blue-Green Algae," by G. P. Fitzgerald, G. C. Gerloff, and Folke Skoog, University of Wisconsin, Madison, Wis.

On the evening of June 25, an enjoyable social hour sponsored by members of the Water and Sewage Works Manufacturers' Association preceded a Smorgasbord and Entertainment.

The morning session on June 26 opened with the movie, "Pipeline to the Clouds," and continued with the following papers:

"Reducing Milk Waste in Dairy Plants," by V. Schwarzkopf, Lathrop-Paulson Company, Chicago, Ill.

"The Use of Biological Treatment Methods in the Disposal of Radioactive Wastes," by C. C. Ruehhoft and L. R. Setter, U.S.P.H.S., Cincinnati, Ohio.

"A Quarter of a Century of Sewage Treatment in the Central States," by F. W. Mohlman, Director of Laboratories, Sanitary District of Chicago, Chicago, Ill.

The afternoon session on June 26 consisted of the Annual Business Meeting, followed by inspection trips to the Madison Metropolitan Sewerage District's Nine Springs treatment plant and pumping stations, and the Oscar Mayer and Company packinghouse waste treatment operations, grease flotation unit, trickling filters, and spray irrigation.

At the Annual Banquet, held that evening, announcement was made of the nomination of Don E. Bloodgood to receive the Federation's Arthur Sidney Bedell Award.

The morning session of June 27 consisted of an "Operators' Breakfast," in which open discussion on plant operation problems was stimulated and guided by a panel.

Officers elected for 1952–53 were:

President: W. W. Mathews, Gary, Ind.
1st Vice-President: E. Hurwitz, Chicago, Ill.
2nd Vice-President: O. J. Muegge, Madison, Wis.
3rd Vice-President: A. J. Duvall, St. Paul, Minn.
Secretary-Treasurer: A. Paul Troemper, Springfield, Ill.

A. PAUL TROEMPER,
Secretary-Treasurer

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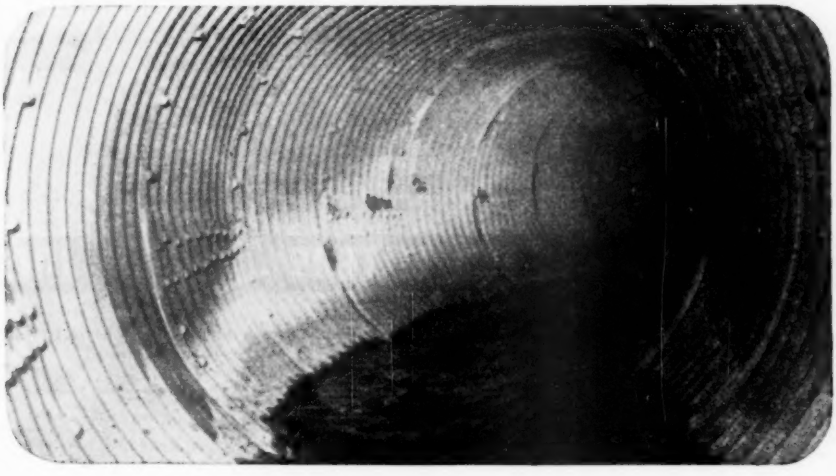

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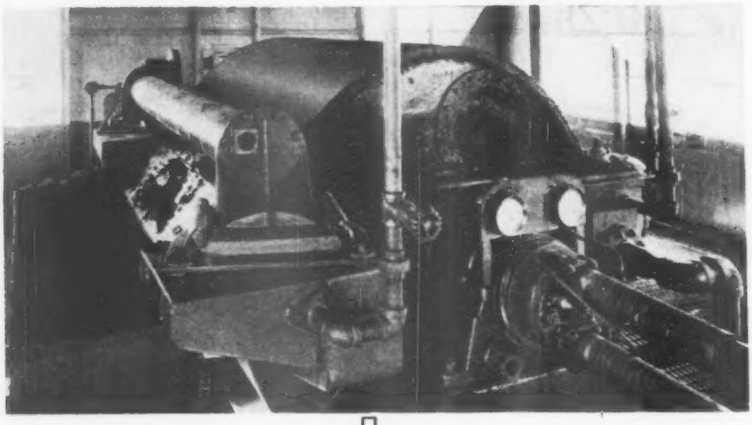

45 years experience with all types of *industrial* filtration problems

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Municipal sanitation is rapidly having the words "including industrial waste disposal" added to it. Most cities and towns are being faced (1) with a combination job of either handling a mixture of industrial wastes and municipal sewage or (2) of working with industrial plants to eliminate the wastes, keeping them out of rivers and ponds and off the land.

Where filtration is likely to play a part, you will find it advantageous to call on Oliver United for guidance. No one knows filtrations—both industrial and sanitary—better than our engineers. And now that the two are combining with increasing frequency, this two-fold experience should be very helpful to you. A letter or phone call to our nearest office will receive prompt attention. Meanwhile, if you would like copies of our Sludge Filter Bulletin (No. 219) and our General Bulletin No. 10-G, we shall be glad to send you copies.

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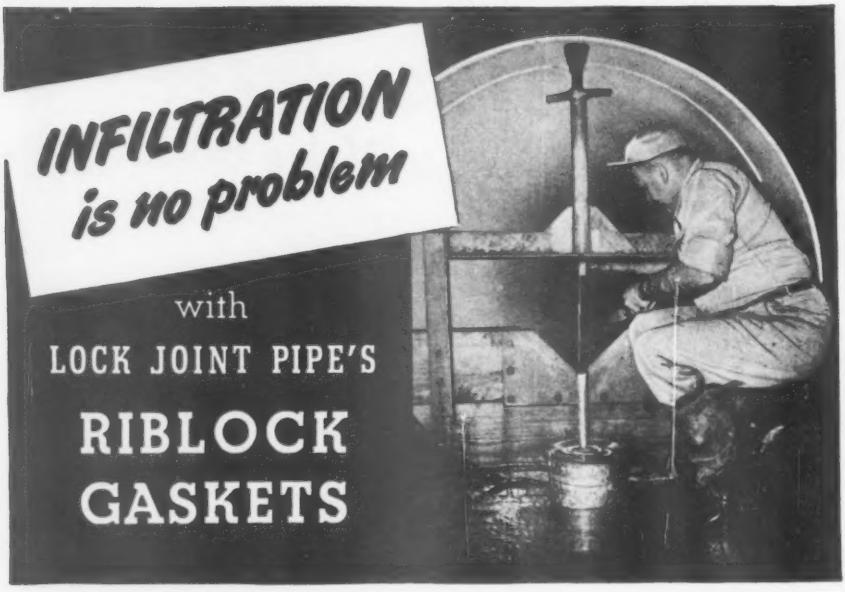

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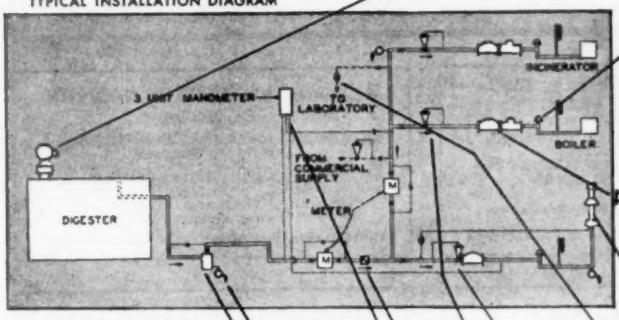
• • • • •

TYPICAL INSTALLATION DIAGRAM



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"VAREC" Drip Trap—Fig. 245 or 248.

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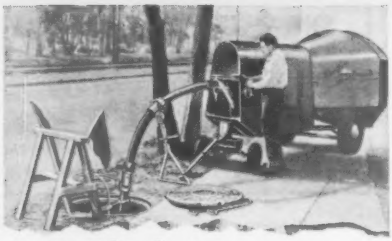

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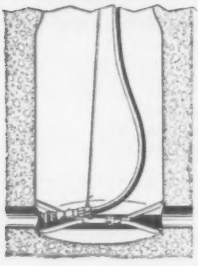

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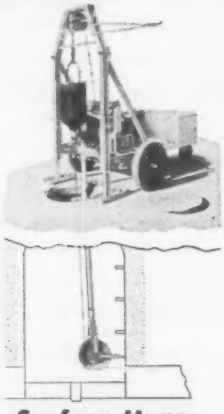

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	Page
American Car and Foundry Company	4a
Armco Drainage and Metal Products, Incorporated	8a
Bailey Meter Company	23a
Builders-Providence, Incorporated	30a
Chain Belt Company	2a
Chapman Valve Manufacturing Company	14a
Chicago Pump Company	20a
Combustion Engineering-Superheater, Inc. (Flash Dryer Division)	1a
Dorr Company, The	12a
Economy Pumps, Incorporated (Division, C. H. Wheeler Manufacturing Co.)	10a
Flexible Sewer-Rod Equipment Company	11a
General Electric Company	28a
Johns-Manville Corporation	14a
Link-Belt Company	8a
Lock Joint Pipe Company	12a
National Clay Pipe Manufacturers, Incorporated	26a
Oliver United Filters, Incorporated	23a
Pacific Flush Tank Company	29a
Rockwell Manufacturing Company (Pittsburgh Valve Division)	31a
Simplex Valve and Meter Company	15a
Snow Irrigation Supply Company	5a
United States Pipe and Foundry Company	24a
Vapor Recovery Systems Company	16a
Walker Process Equipment, Incorporated	31a
Wallace and Tiernan Company, Incorporated	22a
Wood Company, R. D.	Back cover
Yeomans Brothers Company	13a

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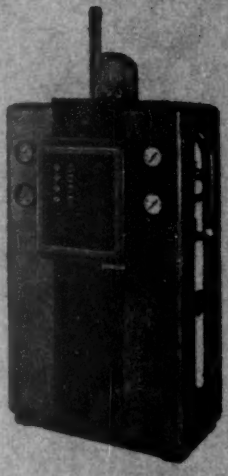

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